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(54) **HARVESTING MACHINE CONTROL SYSTEM WITH FILL LEVEL PROCESSING BASED ON YIELD DATA**

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CPC ***A01D 41/127*** (2013.01); ***G05D 1/0212*** (2013.01); *G05D 2201/0201* (2013.01)

(58) **Field of Classification Search**
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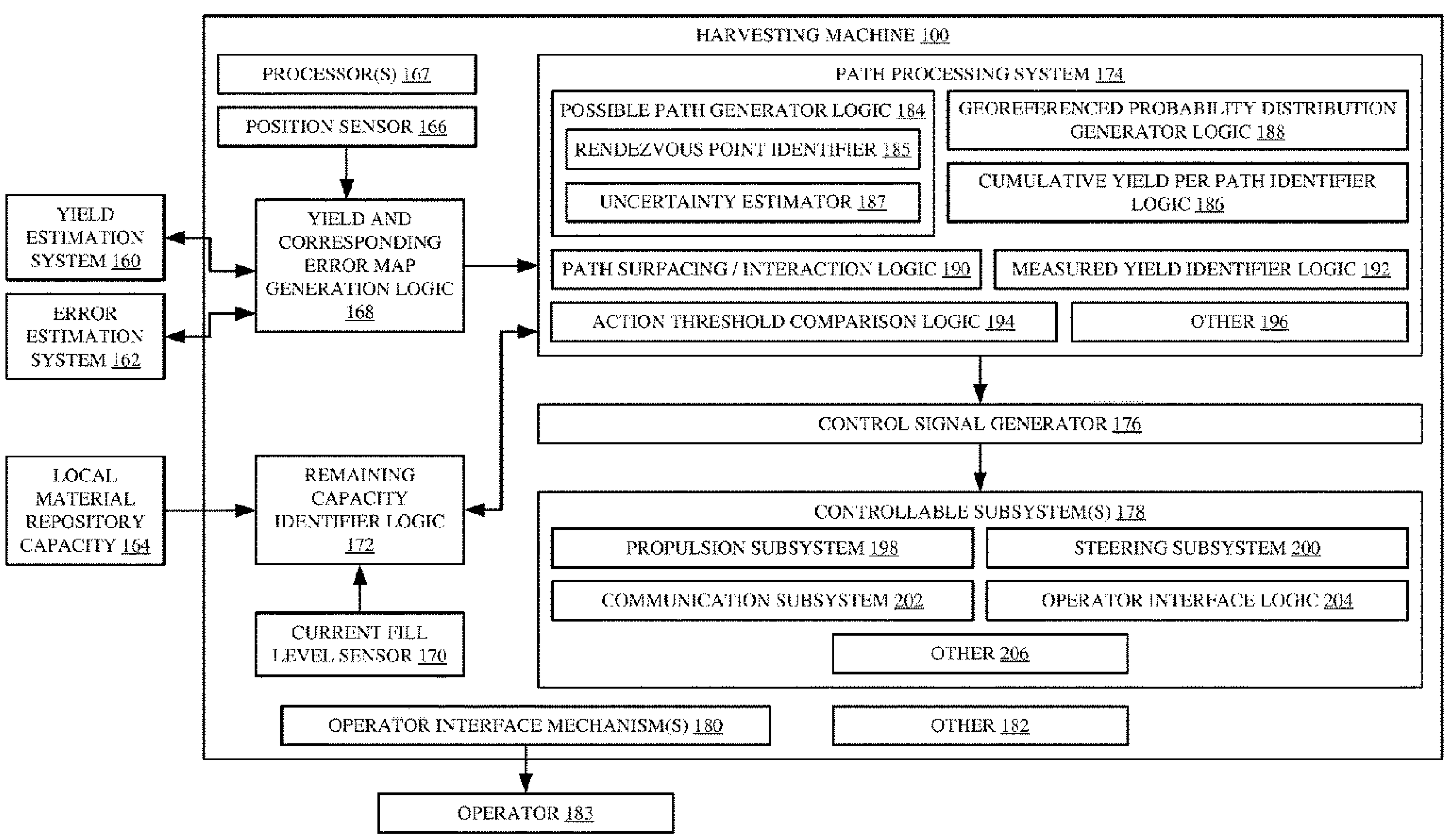
(57) **ABSTRACT**

An agricultural harvesting machine comprises a path processing system that obtains a predicted crop yield at a plurality of different field segments along a harvester path on a field, and obtains field data corresponding to one or more of the field segments generated based on sensor data as the agricultural harvesting machine is performing a crop processing operation. A yield correction factor is generated based on the received field data and the predicted crop yield at the one or more field segments. Based on applying the yield correction factor to the predicted crop yield, a georeferenced probability metric is generated indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field. A control signal generator generates a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

20 Claims, 16 Drawing Sheets



(58) **Field of Classification Search**
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See application file for complete search history.

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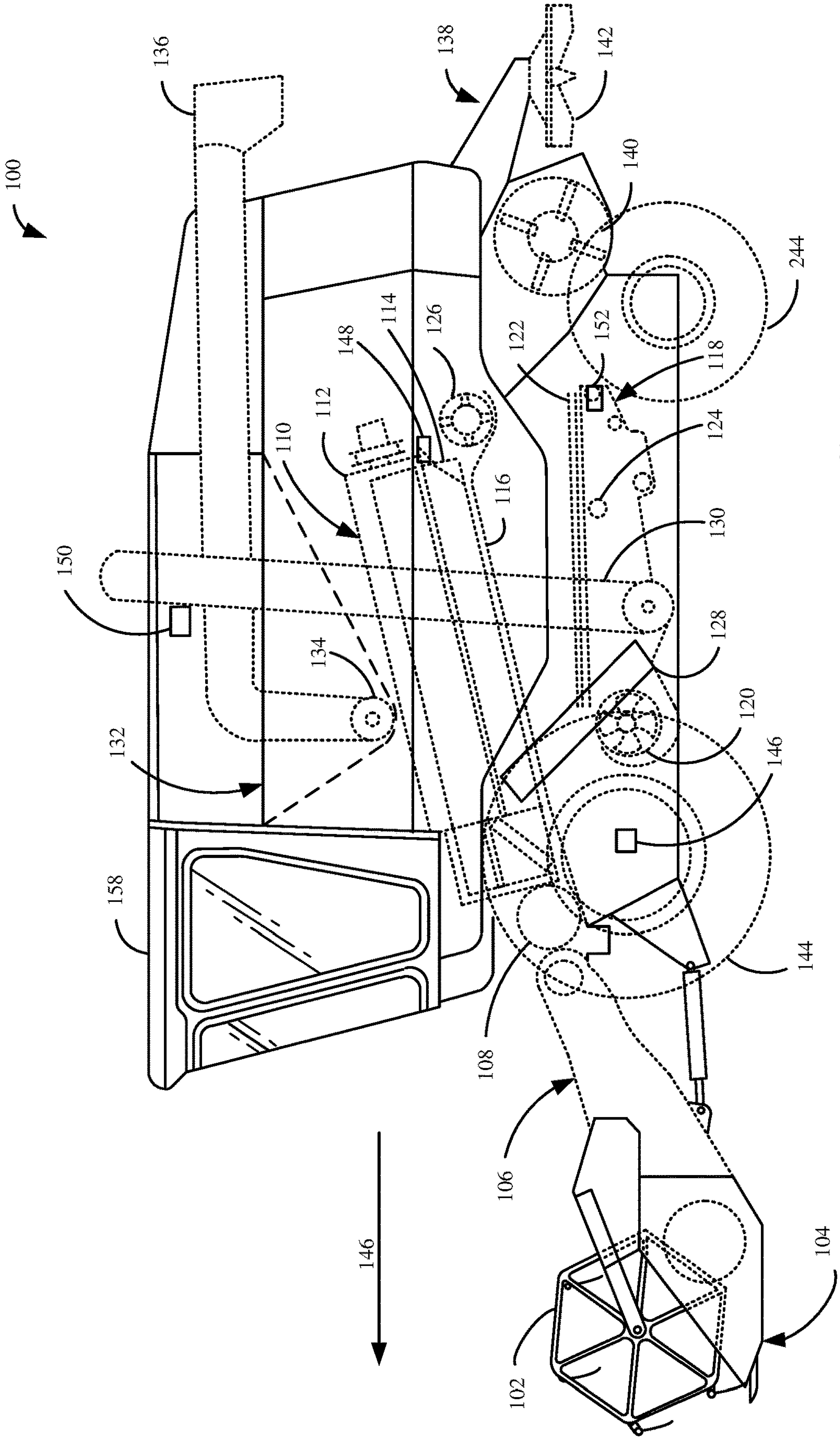
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142
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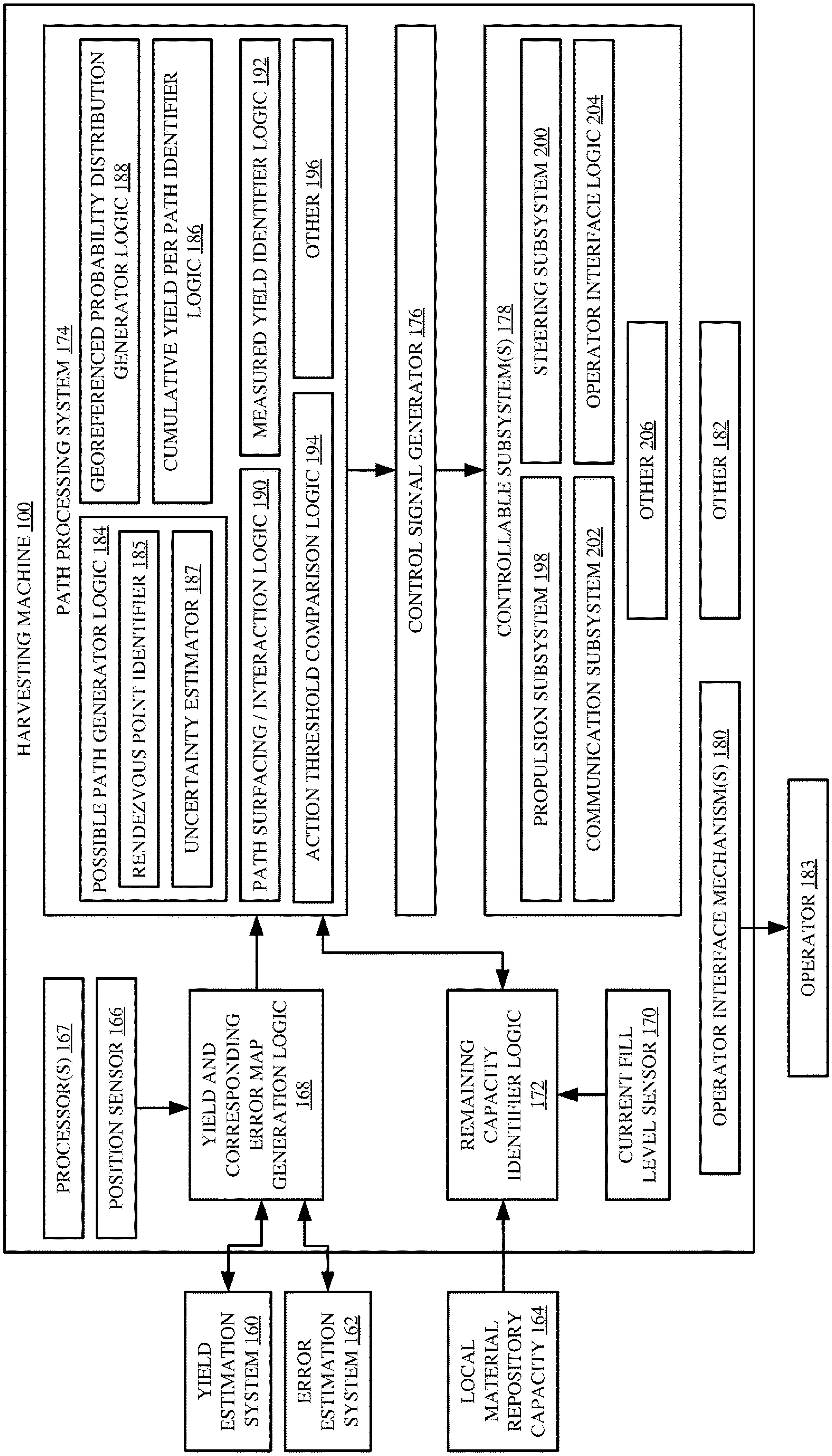
104
102

FIG. 1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PATH PROCESSING SYSTEM 174
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RENDEZVOUS POINT IDENTIFIER 185
UNCERTAINTY ESTIMATOR 187
GEOREFERENCED PROBABILITY DISTRIBUTION GENERATOR LOGIC 188
CUMULATIVE YIELD PER PATH IDENTIFIER LOGIC 186
PATH SURFACING / INTERACTION LOGIC 190
MEASURED YIELD IDENTIFIER LOGIC 192
ACTION THRESHOLD COMPARISON LOGIC 194
OTHER 196
CONTROL SIGNAL GENERATOR 176
CONTROLLABLE SUBSYSTEM(S) 178
PROPULSION SUBSYSTEM 198
STEERING SUBSYSTEM 200
COMMUNICATION SUBSYSTEM 202
OPERATOR INTERFACE LOGIC 204
OTHER 206
OTHER 182
OPERATOR INTERFACE MECHANISM(S) 180
OPERATOR 183
PROCESSOR(S) 167
POSITION SENSOR 166
YIELD AND CORRESPONDING ERROR MAP GENERATION LOGIC 168
REMAINING CAPACITY IDENTIFIER LOGIC 172
CURRENT FILL LEVEL SENSOR 170
YIELD ESTIMATION SYSTEM 160
ERROR ESTIMATION SYSTEM 162
LOCAL MATERIAL REPOSITORY CAPACITY 164

FIG. 2

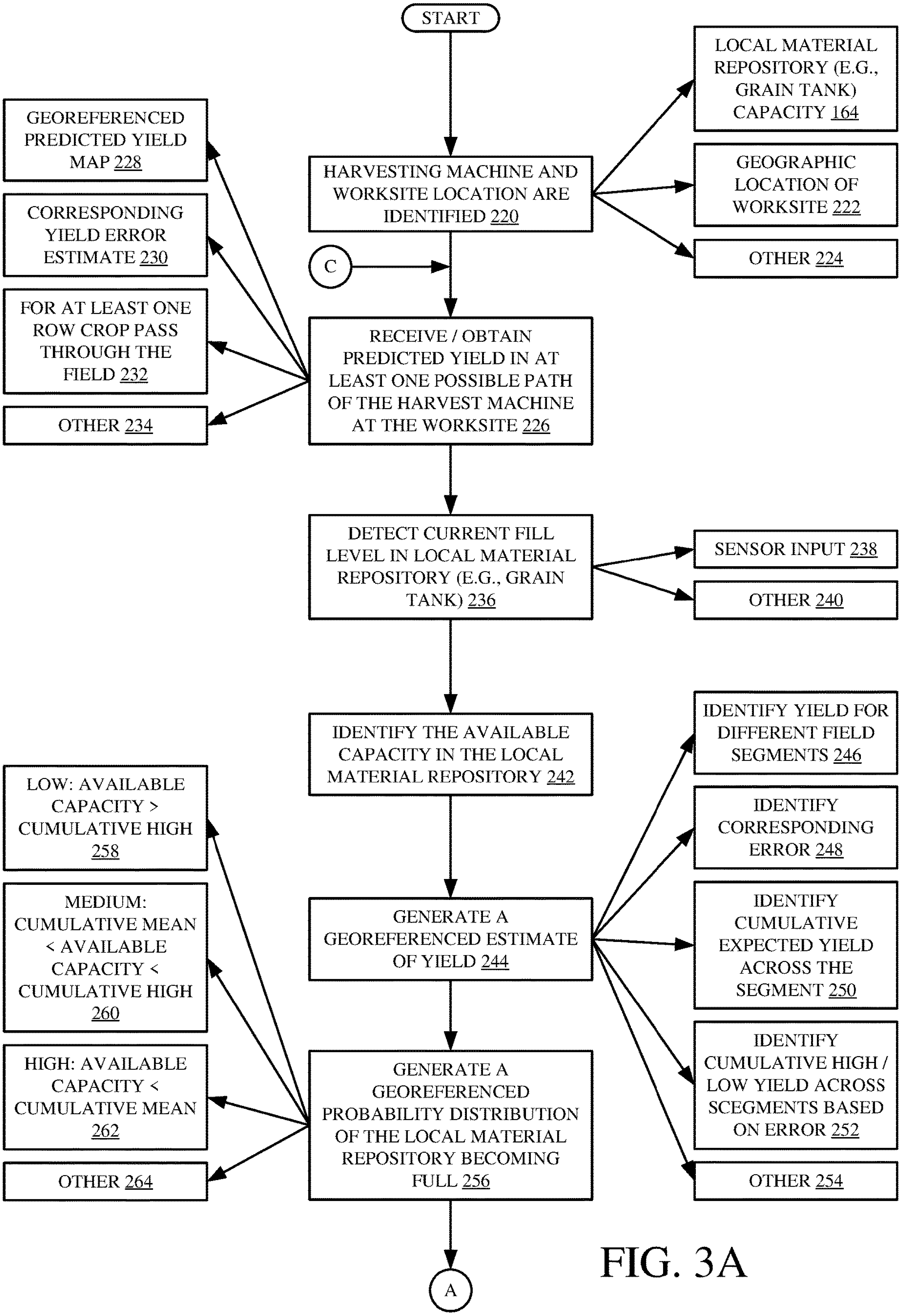

START
LOCAL MATERIAL REPOSITORY (E.G., GRAIN TANK) CAPACITY 164
GEOREFERENCED PREDICTED YIELD MAP 228
HARVESTING MACHINE AND WORKSITE LOCATION ARE IDENTIFIED 220
GEOGRAPHIC LOCATION OF WORKSITE 222
CORRESPONDING YIELD ERROR ESTIMATE 230
C
OTHER 224
FOR AT LEAST ONE ROW CROP PASS THROUGH THE FIELD 232
RECEIVE / OBTAIN PREDICTED YIELD IN AT LEAST ONE POSSIBLE PATH OF THE HARVEST MACHINE AT THE WORKSITE 226
OTHER 234
DETECT CURRENT FILL LEVEL IN LOCAL MATERIAL REPOSITORY (E.G., GRAIN TANK) 236
SENSOR INPUT 238
OTHER 240
IDENTIFY THE AVAILABLE CAPACITY IN THE LOCAL MATERIAL REPOSITORY 242
IDENTIFY YIELD FOR DIFFERENT FIELD SEGMENTS 246
LOW: AVAILABLE CAPACITY > CUMULATIVE HIGH 258
IDENTIFY CORRESPONDING ERROR 248
MEDIUM: CUMULATIVE MEAN < AVAILABLE CAPACITY < CUMULATIVE HIGH 260
GENERATE A GEOREFERENCED ESTIMATE OF YIELD 244
IDENTIFY CUMULATIVE EXPECTED YIELD ACROSS THE SEGMENT 250
HIGH: AVAILABLE CAPACITY < CUMULATIVE MEAN 262
GENERATE A GEOREFERENCED PROBABILITY DISTRIBUTION OF THE LOCAL MATERIAL REPOSITORY BECOMING FULL 256
IDENTIFY CUMULATIVE HIGH / LOW YIELD ACROSS SCEGMENTS BASED ON ERROR 252
OTHER 264
OTHER 254
A

FIG. 3A

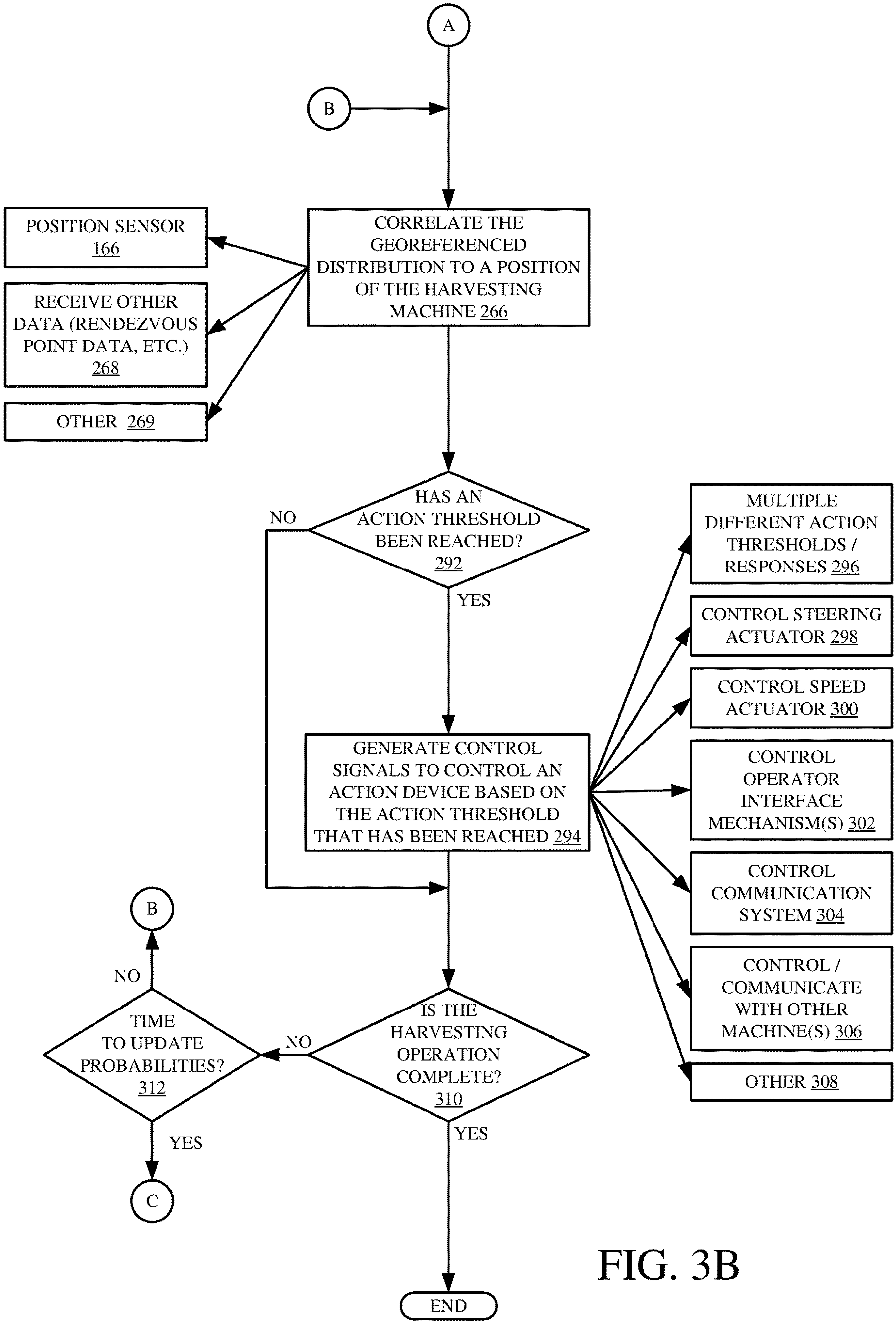

A
B
CORRELATE THE GEOREFERENCED DISTRIBUTION TO A POSITION OF THE HARVESTING MACHINE 266
POSITION SENSOR 166
RECEIVE OTHER DATA (RENDEZVOUS POINT DATA, ETC.) 268
OTHER 269
HAS AN ACTION THRESHOLD BEEN REACHED? 292
NO
YES
MULTIPLE DIFFERENT ACTION THRESHOLDS / RESPONSES 296
CONTROL STEERING ACTUATOR 298
CONTROL SPEED ACTUATOR 300
CONTROL OPERATOR INTERFACE MECHANISM(S) 302
CONTROL COMMUNICATION SYSTEM 304
CONTROL / COMMUNICATE WITH OTHER MACHINE(S) 306
OTHER 308
GENERATE CONTROL SIGNALS TO CONTROL AN ACTION DEVICE BASED ON THE ACTION THRESHOLD THAT HAS BEEN REACHED 294
B
NO
TIME TO UPDATE PROBABILITIES? 312
NO
IS THE HARVESTING OPERATION COMPLETE? 310
YES
YES
C
END

FIG. 3B

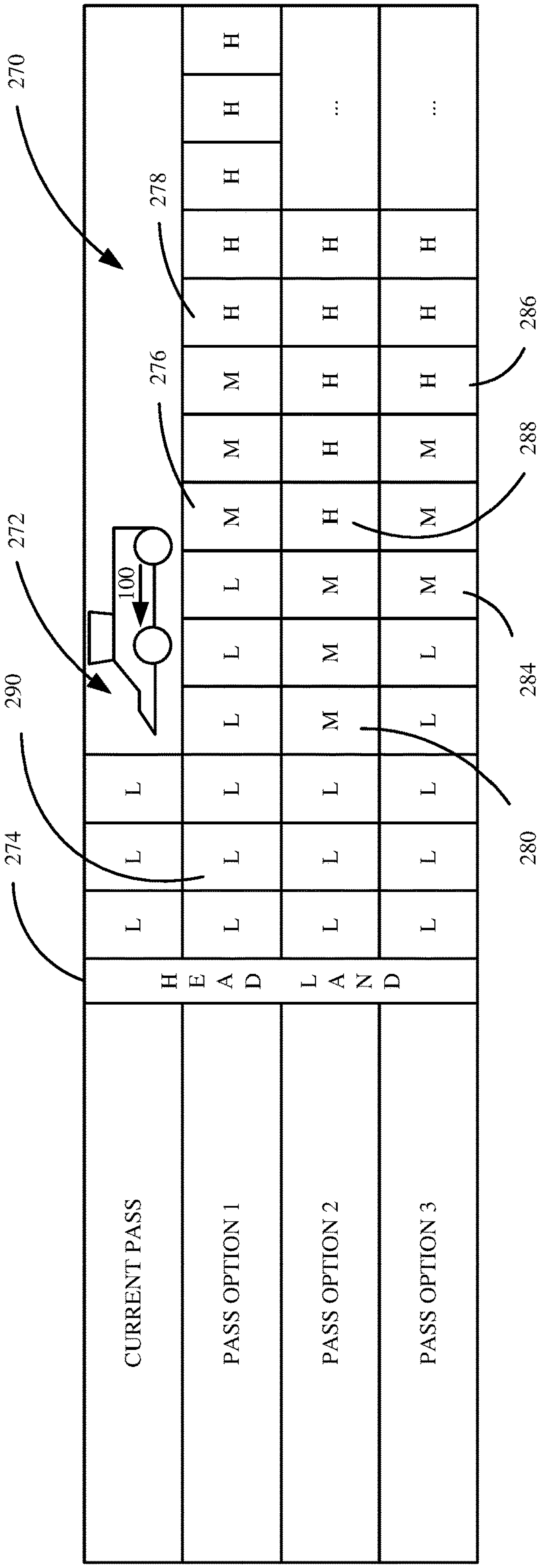

270
272
274
276
278
280
284
286
288
290
100
CURRENT PASS
PASS OPTION 1
PASS OPTION 2
PASS OPTION 3
HEAD LAND

FIG. 3C

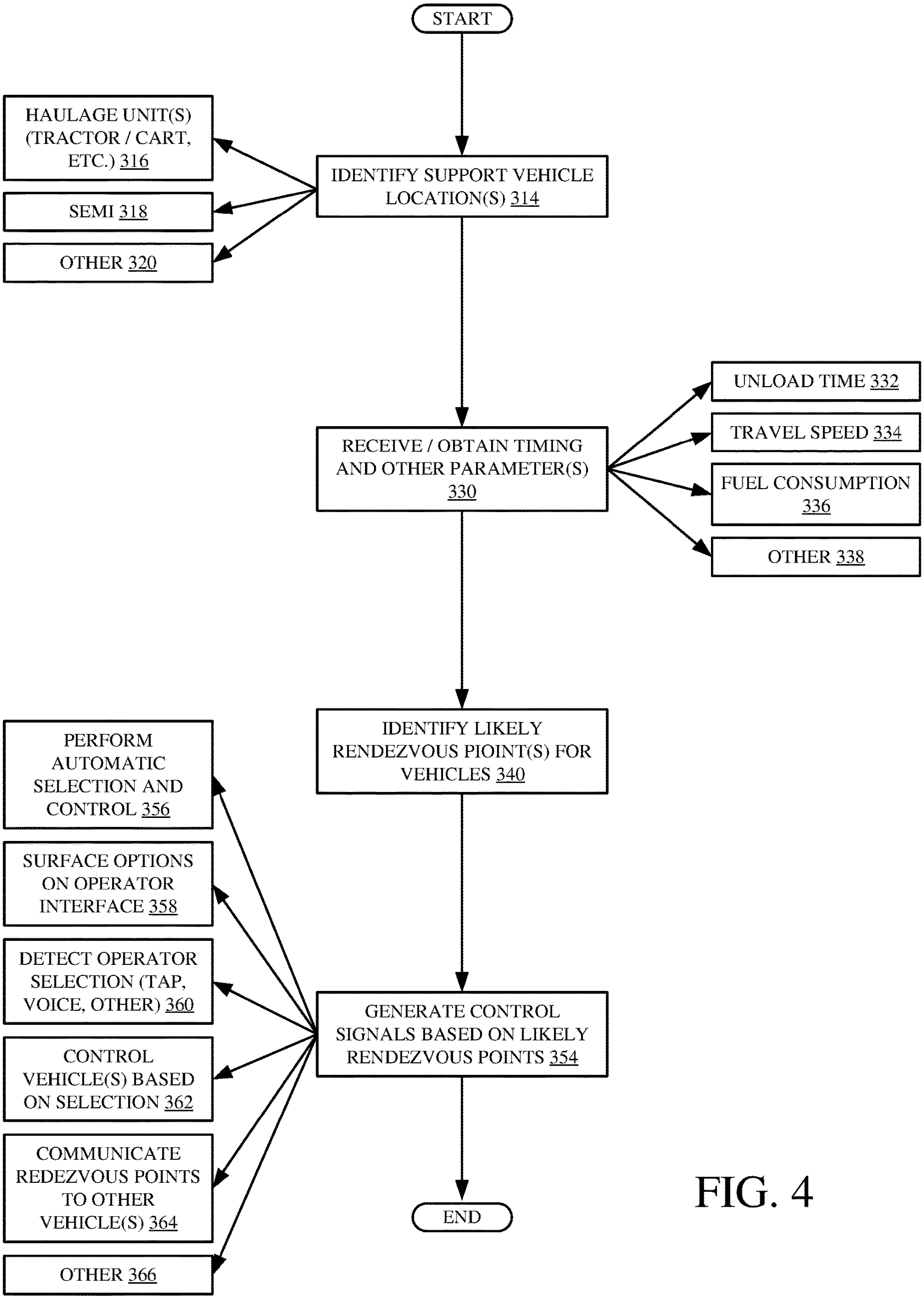
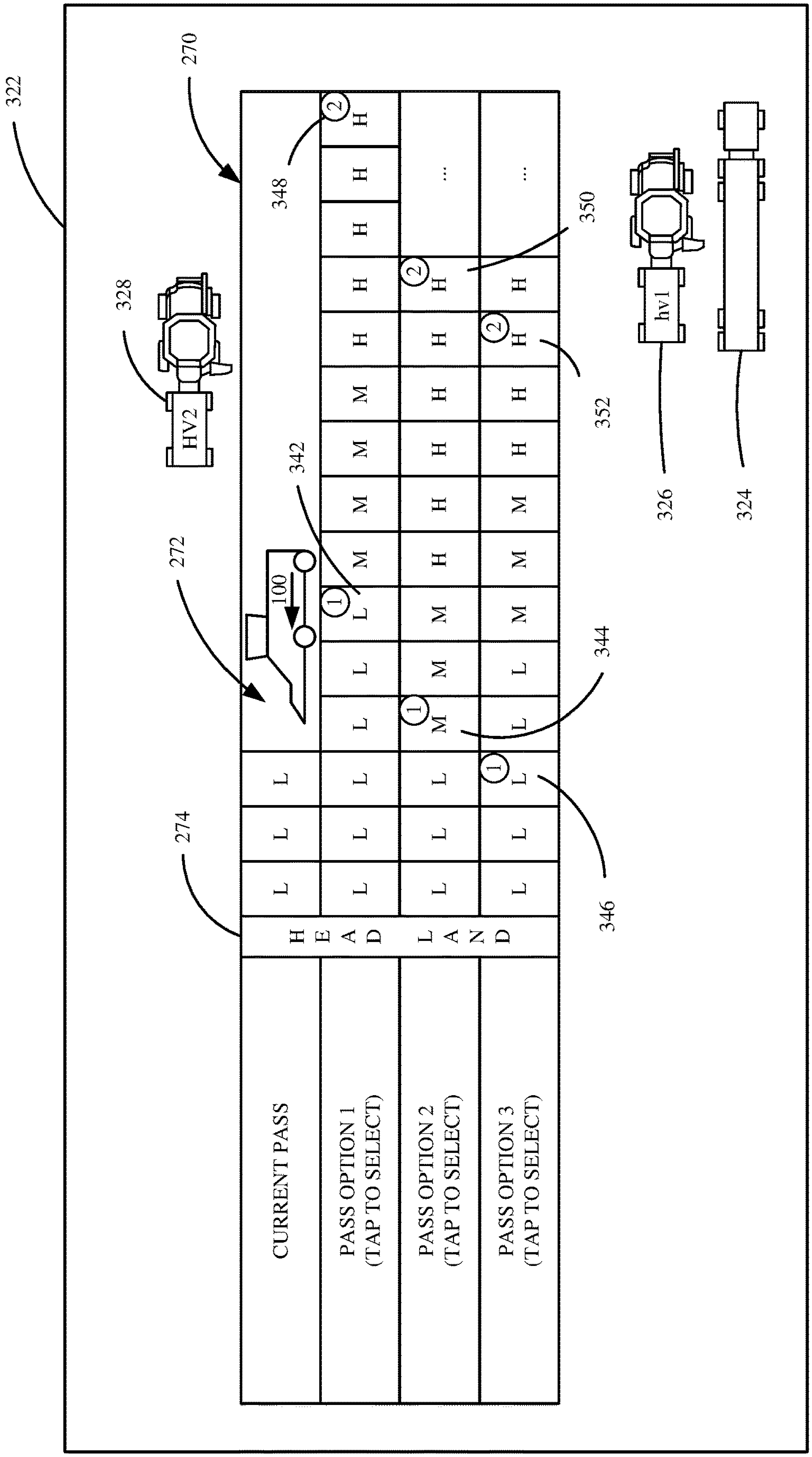
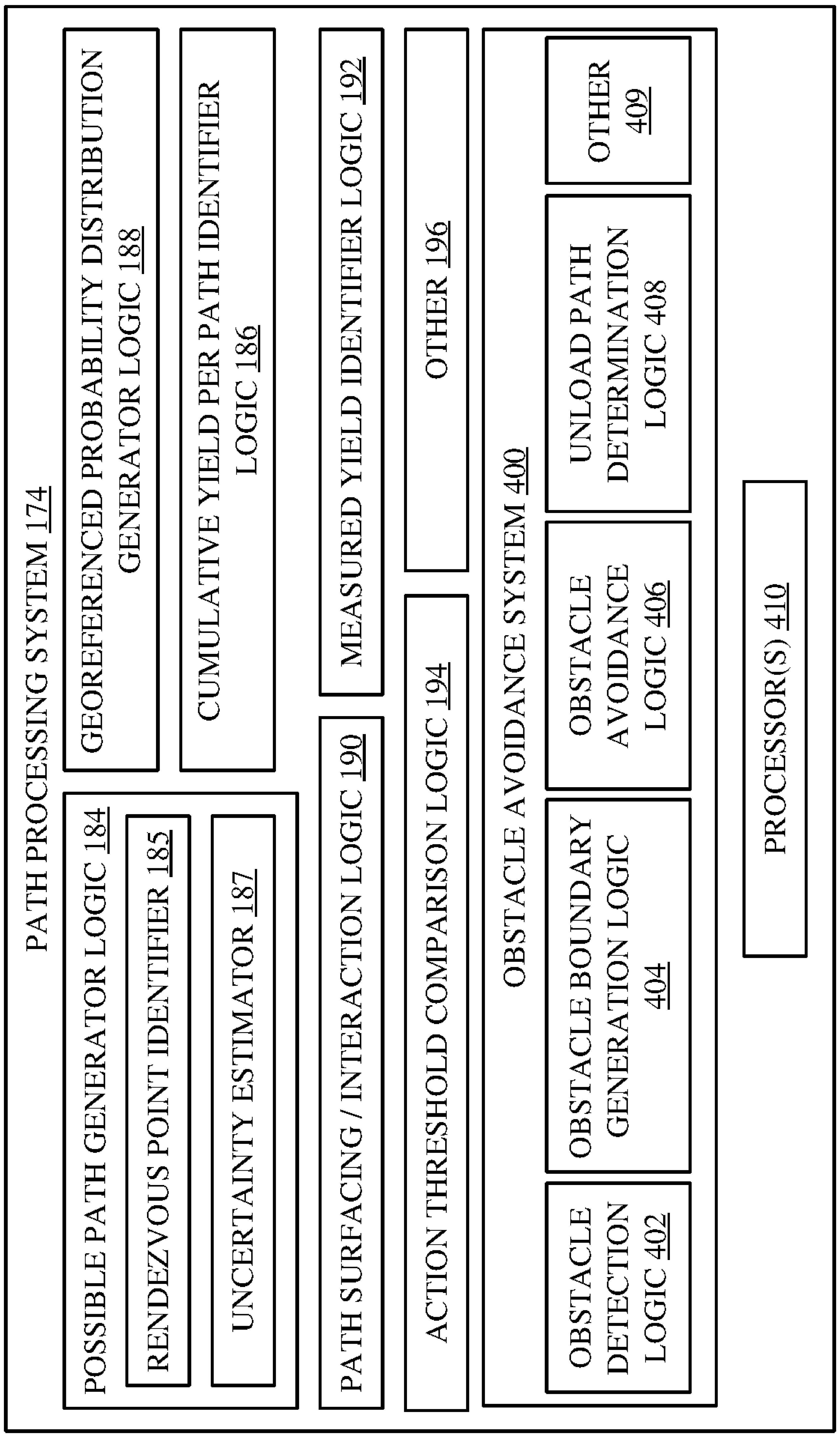

START
IDENTIFY SUPPORT VEHICLE LOCATION(S) 314
HAULAGE UNIT(S) (TRACTOR / CART, ETC.) 316
SEMI 318
OTHER 320
RECEIVE / OBTAIN TIMING AND OTHER PARAMETER(S) 330
UNLOAD TIME 332
TRAVEL SPEED 334
FUEL CONSUMPTION 336
OTHER 338
IDENTIFY LIKELY RENDEZVOUS PIOINT(S) FOR VEHICLES 340
GENERATE CONTROL SIGNALS BASED ON LIKELY RENDEZVOUS POINTS 354
PERFORM AUTOMATIC SELECTION AND CONTROL 356
SURFACE OPTIONS ON OPERATOR INTERFACE 358
DETECT OPERATOR SELECTION (TAP, VOICE, OTHER) 360
CONTROL VEHICLE(S) BASED ON SELECTION 362
COMMUNICATE REDEZVOUS POINTS TO OTHER VEHICLE(S) 364
OTHER 366
END

FIG. 4



322
270
328
HV2
272
100
274
342
344
346
348
350
352
CURRENT PASS
PASS OPTION 1 (TAP TO SELECT)
PASS OPTION 2 (TAP TO SELECT)
PASS OPTION 3 (TAP TO SELECT)
HEAD LAND
hv1
326
324

FIG. 4A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POSSIBLE PATH GENERATOR LOGIC 184
RENDEZVOUS POINT IDENTIFIER 185
UNCERTAINTY ESTIMATOR 187
GEOREFERENCED PROBABILITY DISTRIBUTION GENERATOR LOGIC 188
CUMULATIVE YIELD PER PATH IDENTIFIER LOGIC 186
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MEASURED YIELD IDENTIFIER LOGIC 192
ACTION THRESHOLD COMPARISON LOGIC 194
OTHER 196
OBSTACLE AVOIDANCE SYSTEM 400
OBSTACLE DETECTION LOGIC 402
OBSTACLE BOUNDARY GENERATION LOGIC 404
OBSTACLE AVOIDANCE LOGIC 406
UNLOAD PATH DETERMINATION LOGIC 408
OTHER 409
PROCESSOR(S) 410

FIG. 5

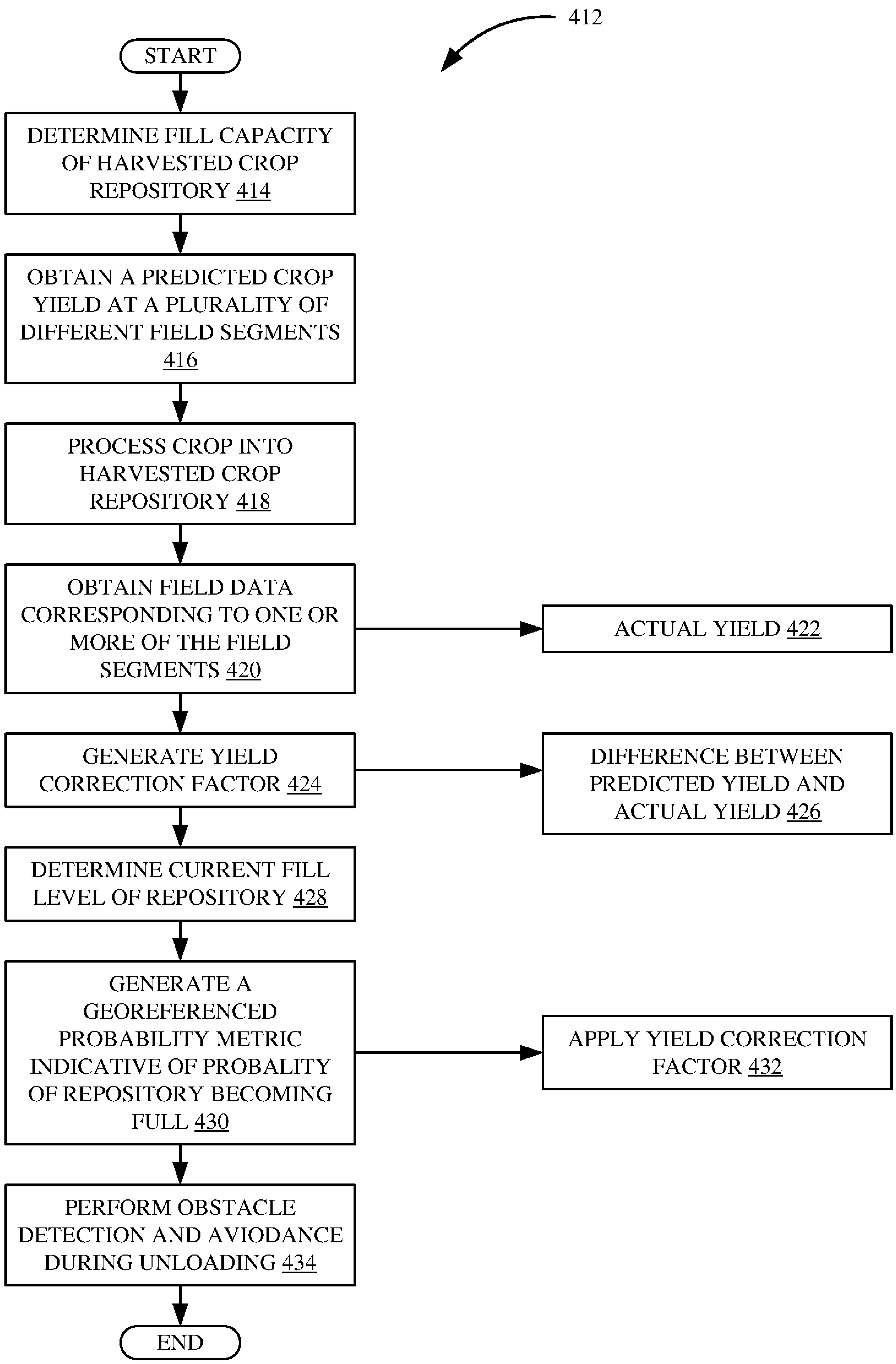
412
START
DETERMINE FILL CAPACITY OF HARVESTED CROP REPOSITORY 414
OBTAIN A PREDICTED CROP YIELD AT A PLURALITY OF DIFFERENT FIELD SEGMENTS 416
PROCESS CROP INTO HARVESTED CROP REPOSITORY 418
OBTAIN FIELD DATA CORRESPONDING TO ONE OR MORE OF THE FIELD SEGMENTS 420
ACTUAL YIELD 422
GENERATE YIELD CORRECTION FACTOR 424
DIFFERENCE BETWEEN PREDICTED YIELD AND ACTUAL YIELD 426
DETERMINE CURRENT FILL LEVEL OF REPOSITORY 428
GENERATE A GEOREFERENCED PROBABILITY METRIC INDICATIVE OF PROBALITY OF REPOSITORY BECOMING FULL 430
APPLY YIELD CORRECTION FACTOR 432
PERFORM OBSTACLE DETECTION AND AVIODANCE DURING UNLOADING 434
END

FIG. 6

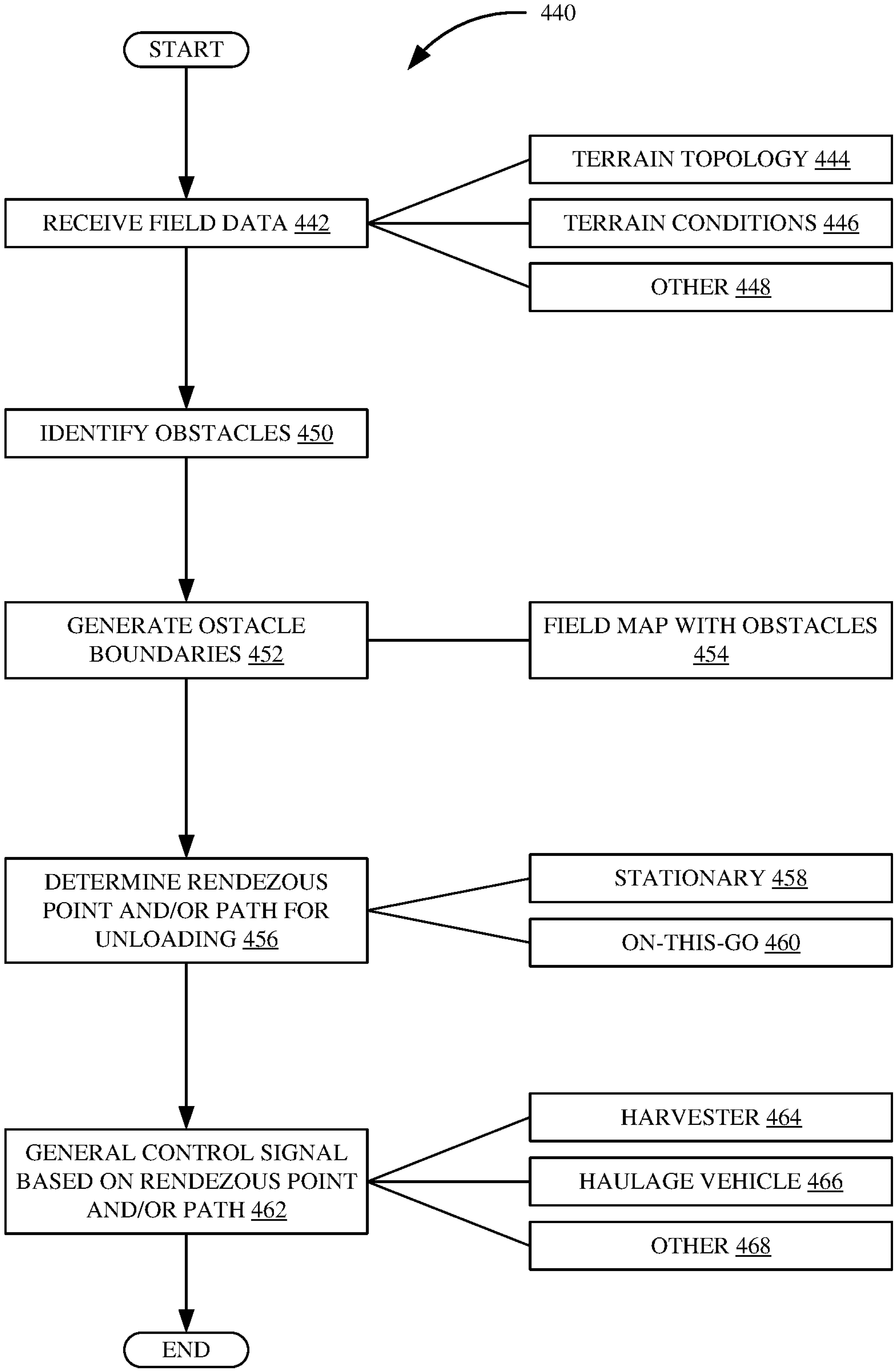
440
START
RECEIVE FIELD DATA 442
TERRAIN TOPOLOGY 444
TERRAIN CONDITIONS 446
OTHER 448
IDENTIFY OBSTACLES 450
GENERATE OSTACLE BOUNDARIES 452
FIELD MAP WITH OBSTACLES 454
DETERMINE RENDEZOUS POINT AND/OR PATH FOR UNLOADING 456
STATIONARY 458
ON-THIS-GO 460
GENERAL CONTROL SIGNAL BASED ON RENDEZOUS POINT AND/OR PATH 462
HARVESTER 464
HAULAGE VEHICLE 466
OTHER 468
END

FIG. 7

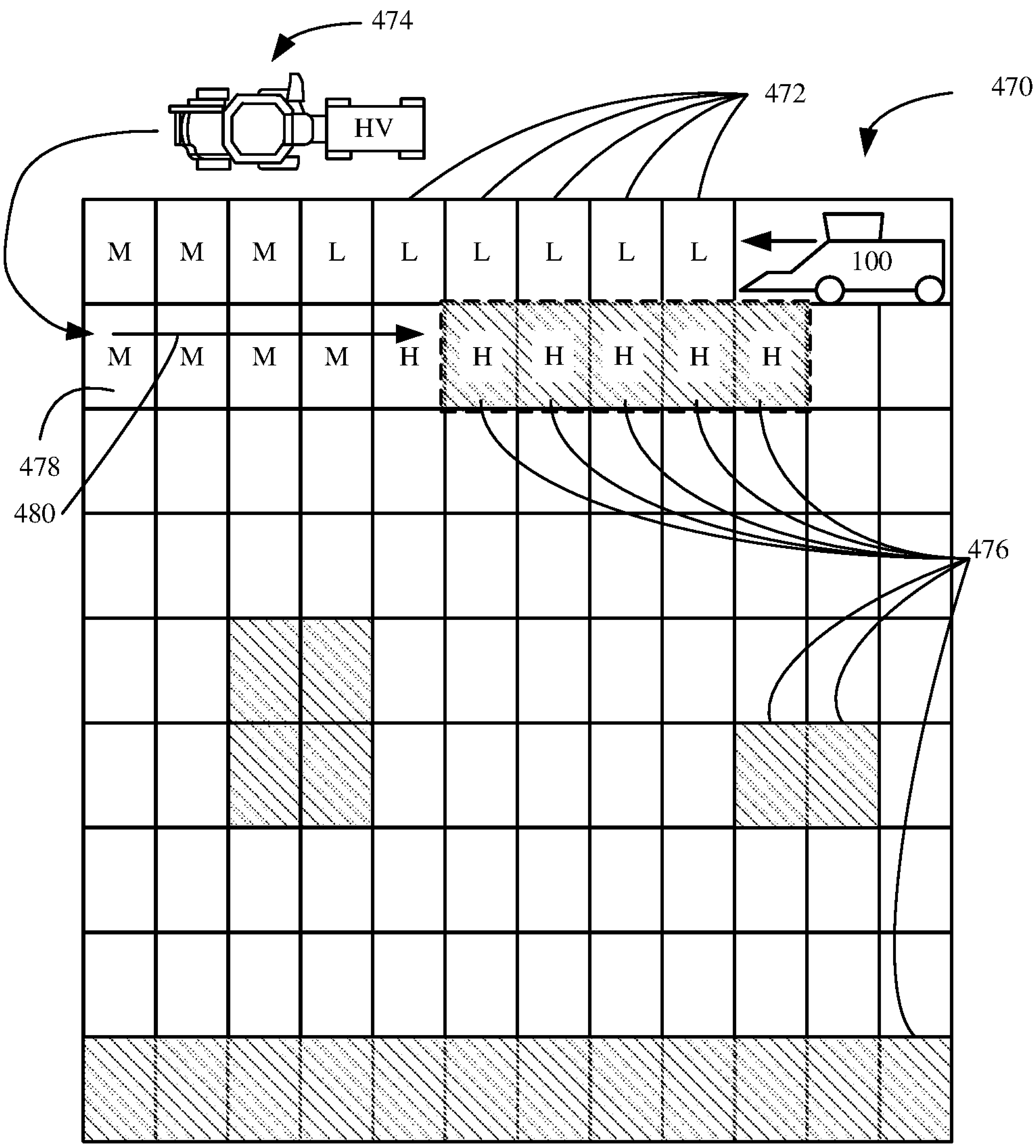

FIG. 8

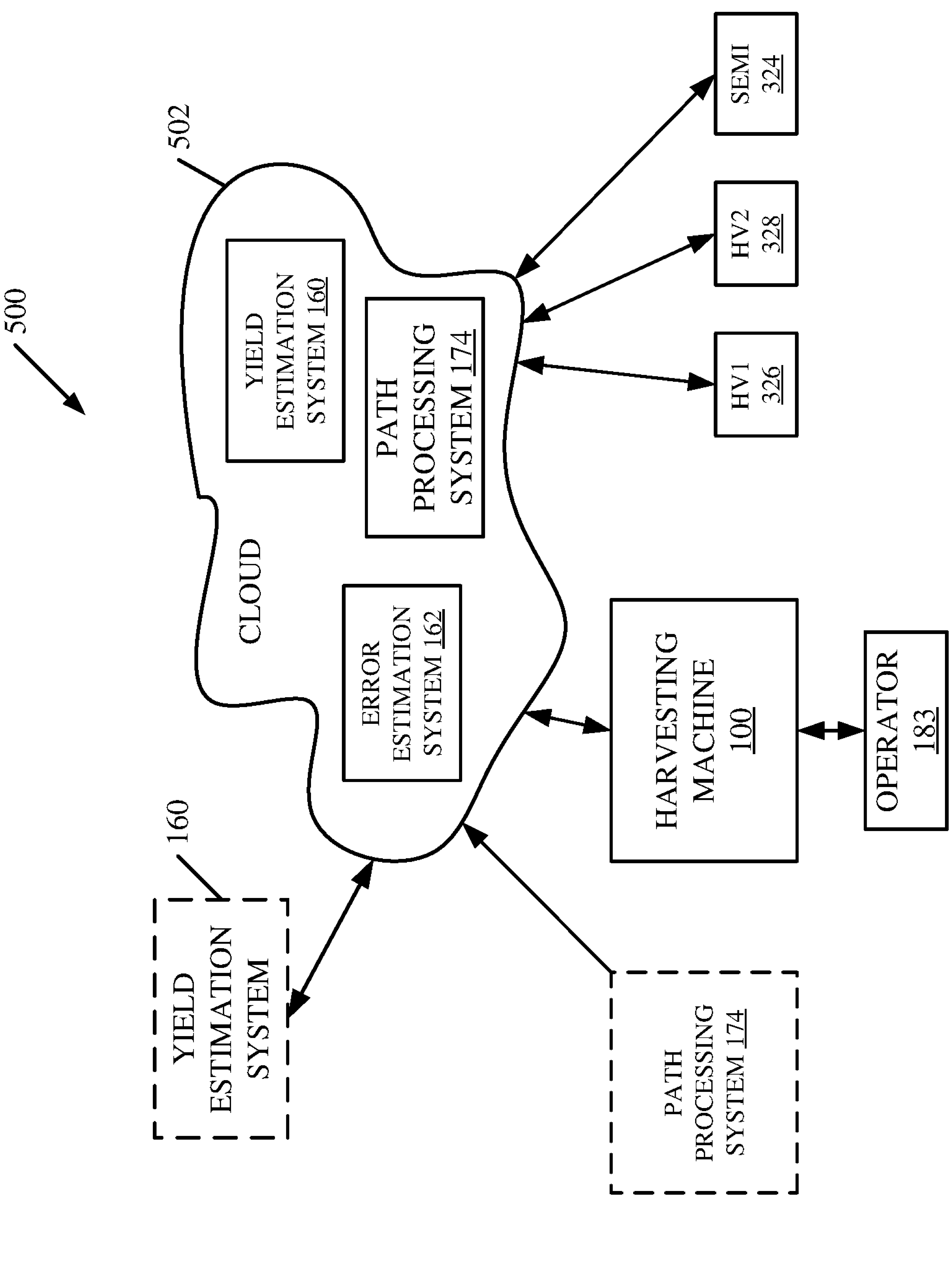
500
502
YIELD ESTIMATION SYSTEM 160
PATH PROCESSING SYSTEM 174
CLOUD
ERROR ESTIMATION SYSTEM 162
SEMI 324
HV2 328
HV1 326
HARVESTING MACHINE 100
OPERATOR 183
160
YIELD ESTIMATION SYSTEM
PATH PROCESSING SYSTEM 174

FIG. 9

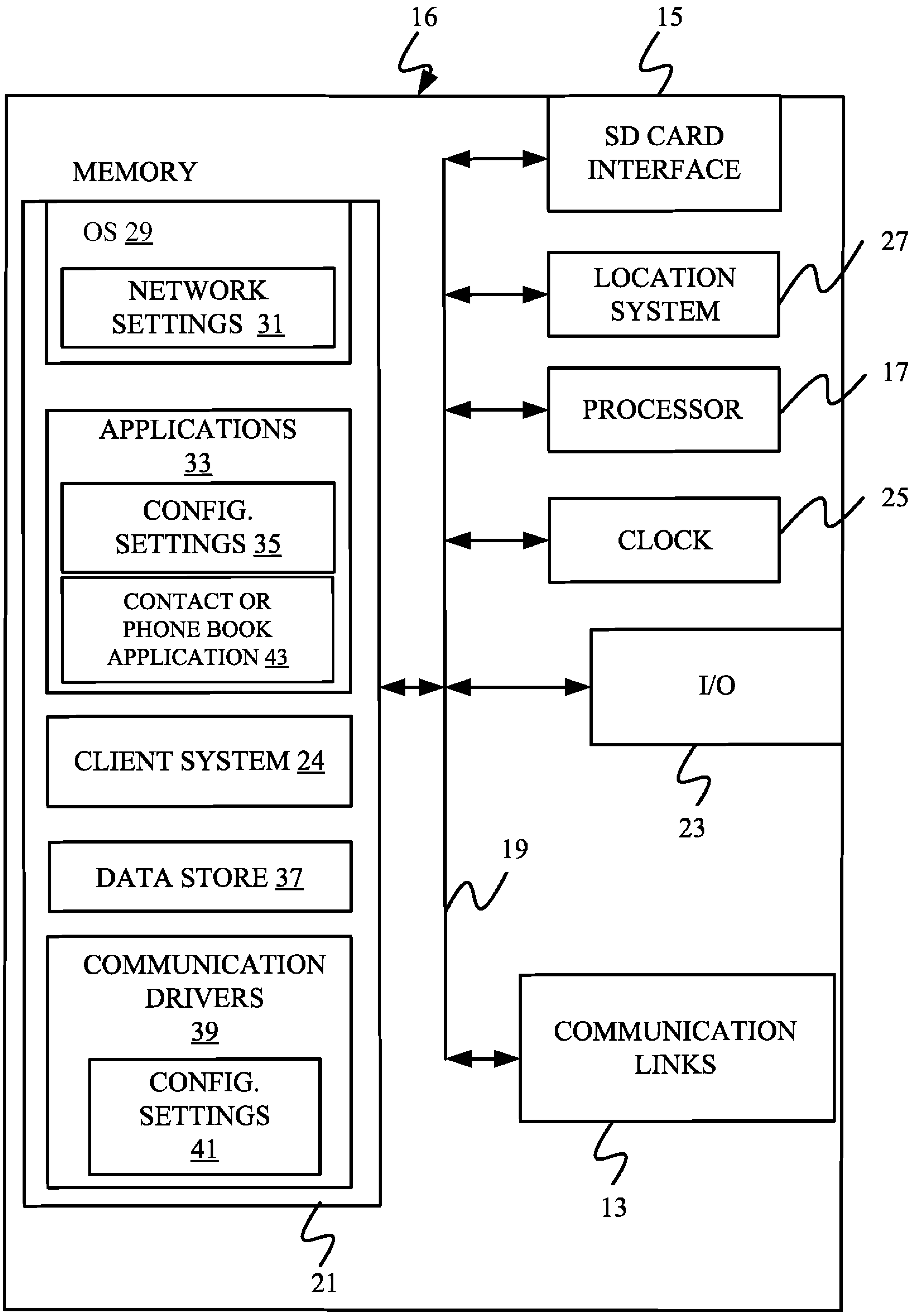
16
15
MEMORY
OS 29
NETWORK SETTINGS 31
APPLICATIONS 33
CONFIG. SETTINGS 35
CONTACT OR PHONE BOOK APPLICATION 43
CLIENT SYSTEM 24
DATA STORE 37
COMMUNICATION DRIVERS 39
CONFIG. SETTINGS 41
21
SD CARD INTERFACE
LOCATION SYSTEM
27
PROCESSOR
17
CLOCK
25
I/O
23
19
COMMUNICATION LINKS
13

FIG. 10

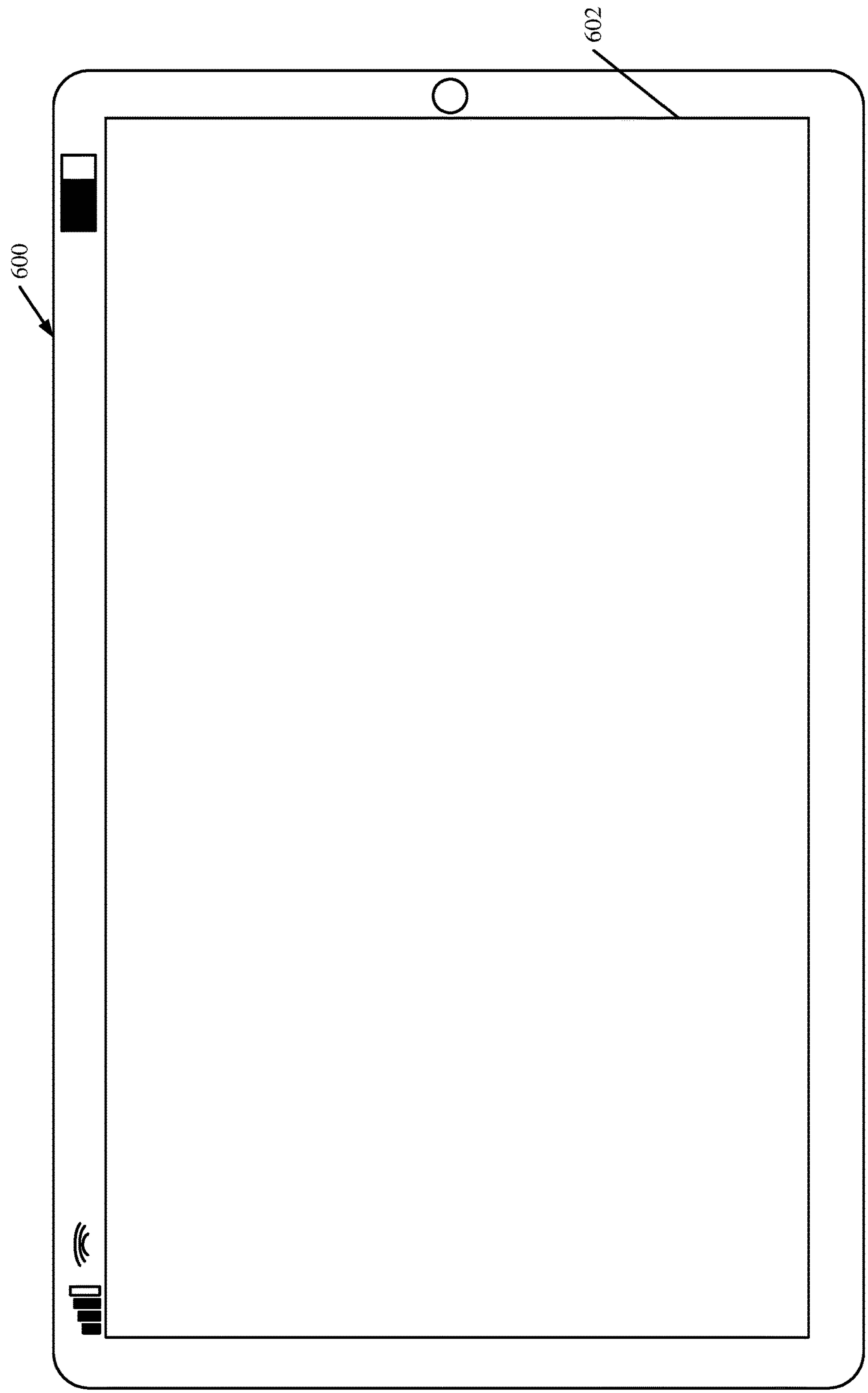

FIG. 11

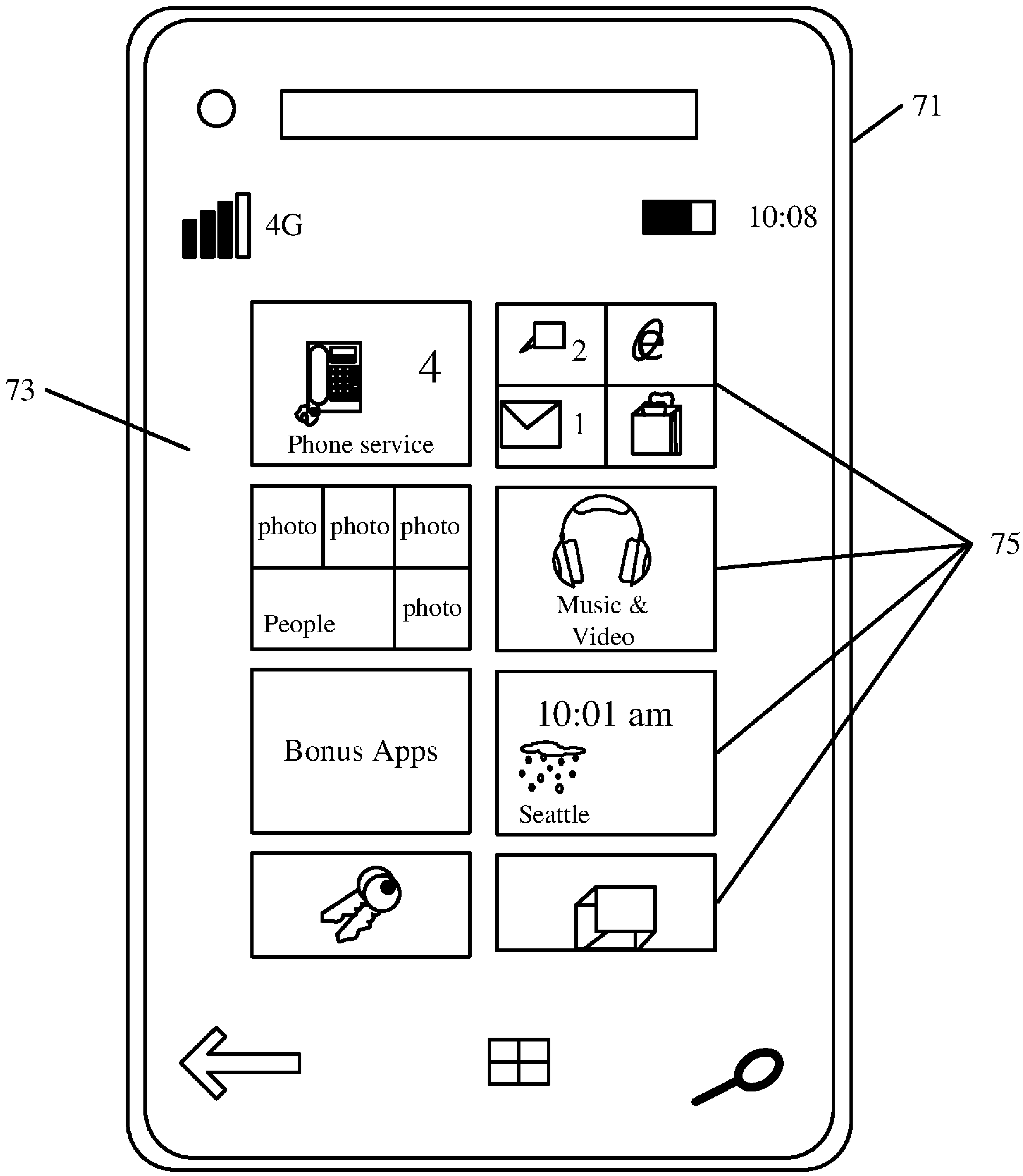
71
4G
10:08
73
4
Phone service
2
1
75
photo
photo
photo
People
photo
Music &
Video
Bonus Apps
10:01 am
Seattle

FIG. 12

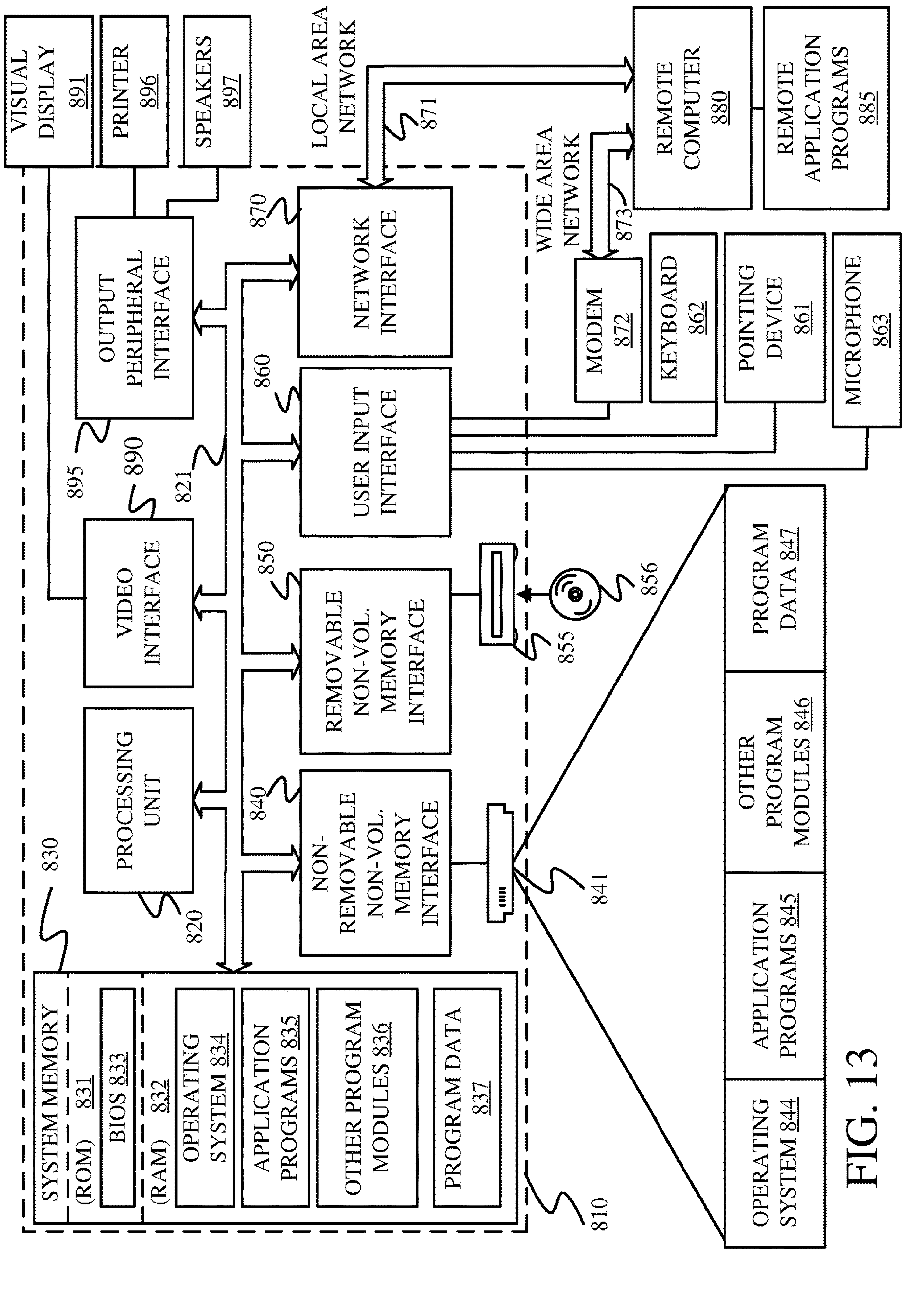
VISUAL DISPLAY 891
PRINTER 896
SPEAKERS 897
LOCAL AREA NETWORK
871
REMOTE COMPUTER 880
REMOTE APPLICATION PROGRAMS 885
WIDE AREA NETWORK
873
OUTPUT PERIPHERAL INTERFACE
870
NETWORK INTERFACE
MODEM 872
KEYBOARD 862
POINTING DEVICE 861
MICROPHONE 863
860
USER INPUT INTERFACE
895
890
821
VIDEO INTERFACE
850
REMOVABLE NON-VOL. MEMORY INTERFACE
856
855
PROCESSING UNIT
830
840
NON-REMOVABLE NON-VOL. MEMORY INTERFACE
841
820
PROGRAM DATA 847
OTHER PROGRAM MODULES 846
APPLICATION PROGRAMS 845
OPERATING SYSTEM 844
SYSTEM MEMORY
(ROM) 831
BIOS 833
(RAM) 832
OPERATING SYSTEM 834
APPLICATION PROGRAMS 835
OTHER PROGRAM MODULES 836
PROGRAM DATA 837
810

FIG. 13

HARVESTING MACHINE CONTROL SYSTEM WITH FILL LEVEL PROCESSING BASED ON YIELD DATA

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of and claims priority of U.S. patent application Ser. No. 16/171,978, filed Oct. 26, 2018, the contents of which are hereby incorporated by reference in their entirety.

FIELD OF THE DESCRIPTION

The present description generally relates to a mobile harvesting machine. More specifically, but not by limitation, the present description relates to controlling a mobile harvesting machine based on fill level prediction using a priori and actual yield data.

BACKGROUND

There are many different types of mobile machines. There are also many different types of mobile machines that have local material storage repositories that store material that is gathered, or that is distributed, by the machine.

For instance, in one example, an agricultural harvester, such as a combine harvester, harvests material, such as grain. In harvesting grain, it processes the grain and stores it in a clean grain tank. When the clean grain tank is full, the combine harvester unloads the clean grain into a haulage unit, which may be a grain cart pulled by a tractor. The haulage unit then often transports the harvested grain to another vehicle, such as a semi-truck for transport to a different location.

Other examples of mobile work machines that collect material include machines such as a sugarcane harvester, a forage harvester, a baler, a timber harvester, an asphalt milling machine, a scraper, among a wide variety of other machines.

With these types of machines, logistical efficiency can be desirable. For instance, if a combine harvester reaches its full capacity at some point in a field, and there is no haulage unit nearby, then the combine harvester sits idle, waiting to unload its clean grain tank, until a haulage unit arrives. This increases the inefficiency of the combine harvester, and of the overall harvesting operation.

Similarly, in a given harvesting operation, there may be multiple different combine harvesters operating in a single field, along with multiple different haulage units. If the haulage units go to the wrong harvester (e.g., if they go to a harvester that is not yet at its full capacity, while a different harvester is already at its full capacity), this can also raise the inefficiency of the operation. Further, it may be that the operators of the haulage units do not know when a particular combine harvester is reaching its capacity.

Machines that distribute material often also have a local repository that stores the material to be distributed. Such agricultural machines include sprayers or other vehicles that apply fertilizer or other chemicals to a field. In operation, the sprayer is often loaded with fertilizer or another chemical and distributes it on a field. When the local storage repository (e.g., the tank) becomes empty, the sprayer or the other vehicle must have more fertilizer or chemical loaded into it.

The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

SUMMARY

An agricultural harvesting machine comprises a harvested crop repository having a fill capacity, a crop processing functionality configured to engage crop in a field, perform a crop processing operation on the crop, and move the processed crop to the harvested crop repository, and a fill level sensor configured to generate a fill level signal indicative of a current fill level of the harvested crop repository. A path processing system is configured to obtain a predicted crop yield at a plurality of different field segments along a harvester path on the field, obtain field data corresponding to one or more of the field segments, the field data being generated based on sensor data from a sensor on the agricultural harvesting machine as the agricultural harvesting machine is performing the crop processing operation, generate a yield correction factor based on the received field data and the predicted crop yield at the one or more field segments, based on applying the yield correction factor to the predicted crop yield, and generate a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field. A control signal generator is configured to generate a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The claimed subject matter is not limited to implementations that solve any or all disadvantages noted in the background.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial pictorial, partial schematic view of one example of an agricultural harvesting machine (a combine harvester).

FIG. **2** is a block diagram showing one example of different portions of the harvesting machine illustrated in FIG. **1**, in more detail.

FIGS. **3**A and **3**B (collectively referred to herein as FIG. **3**) show a flow chart illustrating one example of the operation of a harvesting machine.

FIG. **3**C is a pictorial illustration of one example of a user interface display.

FIG. **4** is a flow diagram illustrating one example of the operation of a path processing system in an agricultural harvesting machine.

FIG. **4**A is a pictorial illustration showing one example of a user interface display.

FIG. **5** is a schematic diagram of one example of a path processing system.

FIG. **6** is a flow diagram illustrating one example of the operation of a path processing system in an agricultural harvesting machine.

FIG. **7** is a flow diagram illustrating one example of the operation of an obstacle avoidance system in an agricultural harvesting machine.

FIG. **8** is a schematic diagram of an example operation of an obstacle avoidance system in a field.

FIG. **9** is a block diagram showing one example of a harvesting machine deployed in a remote server environment.

FIGS. **10-12** show examples of mobile devices that can be used in the architectures shown in the previous figures.

FIG. **13** is a block diagram showing one example of a computing environment that can be used in the architectures shown in the previous figures.

DETAILED DESCRIPTION

With current combine harvesters, it can be difficult to tell when the clean grain tank is full. It can be even more difficult to predict, where, in the field that is being harvested, the clean grain tank will be full so that a haulage unit can rendezvous with the harvesting machine, at that point, or just prior to that point. Thus, it can be difficult to deploy harvesting machines and haulage units in an efficient manner. The present description thus proceeds with respect to a system in which a yield estimate is received for a field being harvested. The yield estimate can also include an error estimate indicative of a likely error in the yield estimate. The yield estimate and its corresponding error are used to generate a georeferenced probability distribution indicative of different locations where the grain tank on the harvester will likely be full. A control system generates control signals to control different portions of the harvester, based upon the georeferenced probability distribution. This greatly enhances the operation of the harvester, in that it reduces the time that the harvester may be idle and waiting to unload. In addition, the harvester can be automatically controlled to take a path, or to travel at a ground speed, based on a desired rendezvous point with a haulage unit.

The same types of operations can be performed with work other machines that collect material, such as other harvesters, asphalt milling machines, scrapers, etc. The same types of operations can also be performed with respect to machines that distribute material, such as fertilizer or chemical application equipment. In those machines, it can be difficult to know where on a worksite the tank will be empty and need to be refilled. It can also be difficult to know where to rendezvous with a haulage unit used to refill the tank.

These are just examples how of the present description can be applied, and additional examples are provided below, all of which are contemplated herein.

FIG. **1** is a partial pictorial, partial schematic, illustration of an agricultural machine **100**, in an example where machine **100** is a combine harvester (also referred to as harvester or combine **100**). It can be seen in FIG. **1** that combine **100** illustratively includes an operator compartment **101**, which can have a variety of different operator interface mechanisms, for controlling combine **100**. Combine **100** can include a set of front end equipment that can include header **102**, and a cutter generally indicated at **104**. It can also include a feeder house **106**, a feed accelerator **108**, and a thresher generally indicated at **110**. Thresher **110** illustratively includes a threshing rotor **112** and a set of concaves **114**. Further, combine **100** can include a separator **116** that includes a separator rotor. Combine **100** can include a cleaning subsystem (or cleaning shoe) **118** that, itself, can include a cleaning fan **120**, chaffer **122** and sieve **124**. The material handling subsystem in combine **100** can include (in addition to a feeder house **106** and feed accelerator **108**) discharge beater **126**, tailings elevator **128**, clean grain elevator **130** (that moves clean grain into clean grain tank **132**) as well as unloading auger **134** and spout **136**. Combine **100** can further include a residue subsystem **138** that can include chopper **140** and spreader **142**. Combine **100** can also have a propulsion subsystem that includes an engine that drives ground engaging wheels **144** or tracks, etc. It will be noted that combine **100** may also have more than one of any of the subsystems mentioned above (such as left and right cleaning shoes, separators, etc.).

In operation, and by way of overview, combine **100** illustratively moves through a field in the direction indicated by arrow **146**. As it moves, header **102** engages the crop to be harvested and gathers it toward cutter **104**. After it is cut, it is moved through a conveyor in feeder house **106** toward feed accelerator **108**, which accelerates the crop into thresher **110**. The crop is threshed by rotor **112** rotating the crop against concaves **114**. The threshed crop is moved by a separator rotor in separator **116** where some of the residue is moved by discharge beater **126** toward the residue subsystem **138**. It can be chopped by residue chopper **140** and spread on the field by spreader **142**. In other configurations, the residue is simply chopped and dropped in a windrow, instead of being chopped and spread.

Grain falls to cleaning shoe (or cleaning subsystem) **118**. Chaffer **122** separates some of the larger material from the grain, and sieve **124** separates some of the finer material from the clean grain. Clean grain falls to an auger in clean grain elevator **130**, which moves the clean grain upward and deposits it in clean grain tank **132**. Residue can be removed from the cleaning shoe **118** by airflow generated by cleaning fan **120**. Cleaning fan **120** directs air along an airflow path upwardly through the sieves and chaffers and the airflow carries residue can also be rearwardly in combine **100** toward the residue handling subsystem **138**.

Tailings can be moved by tailings elevator **128** back to thresher **110** where they can be re-threshed. Alternatively, the tailings can also be passed to a separate re-threshing mechanism (also using a tailings elevator or another transport mechanism) where they can be re-threshed as well.

FIG. **1** also shows that, in one example, combine **100** can include ground speed sensor **147**, one or more separator loss sensors **148**, a clean grain camera **150**, and one or more cleaning shoe loss sensors **152**. Ground speed sensor **147** illustratively senses the travel speed of combine **100** over the ground. This can be done by sensing the speed of rotation of the wheels, the drive shaft, the axel, or other components. The travel speed can also be sensed by a positioning system, such as a global positioning system (GPS), a dead reckoning system, a LORAN system, or a wide variety of other systems or sensors that provide an indication of travel speed.

Cleaning shoe loss sensors **152** illustratively provide an output signal indicative of the quantity of grain loss by both the right and left sides of the cleaning shoe **118**. In one example, sensors **152** are strike sensors which count grain strikes per unit of time (or per unit of distance traveled) to provide an indication of the cleaning shoe grain loss. The strike sensors for the right and left sides of the cleaning shoe can provide individual signals, or a combined or aggregated signal. It will be noted that sensors **152** can comprise only a single sensor as well, instead of separate sensors for each shoe.

Separator loss sensor **148** provides a signal indicative of grain loss in the left and right separators. The sensors associated with the left and right separators can provide separate grain loss signals or a combined or aggregate signal. This can be done using a wide variety of different types of sensors as well. It will be noted that separator loss sensors **148** may also comprise only a single sensor, instead of separate left and right sensors.

It will also be appreciated that sensor and measurement mechanisms (in addition to the sensors already described) can include other sensors on combine **100** as well. For instance, they can include a residue setting sensor that is configured to sense whether machine **100** is configured to chop the residue, drop a windrow, etc. They can include cleaning shoe fan speed sensors that can be configured proximate fan **120** to sense the speed of the fan. They can include a threshing clearance sensor that senses clearance between the rotor **112** and concaves **114**. They include a threshing rotor speed sensor that senses a rotor speed of rotor **112**. They can include a chaffer clearance sensor that senses the size of openings in chaffer **122**. They can include a sieve clearance sensor that senses the size of openings in sieve **124**. They can include a material other than grain (MOG) moisture sensor that can be configured to sense the moisture level of the material other than grain that is passing through combine **100**. They can include machine setting sensors that are configured to sense the various configurable settings on combine **100**. They can also include a machine orientation sensor that can be any of a wide variety of different types of sensors that sense the orientation of combine **100**. Crop property sensors can sense a variety of different types of crop properties, such as crop type, crop moisture, and other crop properties. They can also be configured to sense characteristics of the crop as they are being processed by combine **100**. For instance, they can sense grain feed rate, as it travels through clean grain elevator **130**. They can sense mass flow rate of grain through elevator **130**, or provide other output signals indicative of other sensed variables. Some additional examples of the types of sensors that can be used are described below.

FIG. **2** is a block diagram showing one example of a portion of harvesting machine (or combine) **100**, in more detail. In the example shown in FIG. **2**, machine **100** is also shown receiving an input from yield estimation system **160**, and error estimation system **162**. It receives an input indicating the capacity of local material repository (e.g., the capacity of clean grain tank **132**). The capacity input is indicated by block **164** in the block diagram of FIG. **2**. It will be appreciated that systems **160** and **162**, and capacity indicator **164**, can all be on machine **100**. They are shown separately for the sake of example only.

Also, FIG. **2** shows that, in one example, machine **100** includes position sensor **166**, processor(s) **167**, yield and corresponding error map generation logic **168**, current fill level sensor **170**, remaining capacity identifier logic **172**, path processing system **174**, control signal generator **176**, controllable subsystems **178**, operator interface mechanisms **180**, and it can include a wide variety of other items **182**. Path processing system **174** illustratively includes possible path generator logic **184** (which can include rendezvous point identifier logic **185** and uncertainty estimator **187** and other items **189**), cumulative yield per path identifier logic **186**, georeferenced probability distribution generator logic **188**, path surfacing/interaction logic **190**, measured yield identifier logic **192**, action threshold comparison logic **194**, and it can include other items **196**. Controllable subsystems **178** can include propulsion subsystem **198**, steering subsystem **200**, communication subsystem **202**, operator interface logic **204**, and it can include other items **206**. The other items can include such things as the material handling subsystem, the cleaning subsystem, and the residue subsystem all discussed above with respect to FIG. **1**. Before describing the operation of harvesting machine **100** in more detail, a brief description of some of the items illustrated in FIG. **2**, and their operation, will first be provided.

Yield estimation system **160** illustratively generates an estimate of yield at different geographic locations in the field being harvested by machine **100**. The yield estimation system **160** can take a wide variety of different forms and illustratively provides a georeferenced a priori estimate of yield. The estimating techniques can include a wide variety of different techniques such as in-season remote sensing, sampling ears from individual plants and extrapolating results across the field, and crop modeling. Yield estimation system **160** may include near real time sensing which may include, for instance, on-board image capture devices (which capture images ahead of machine **100**, or to the sides of machine **100**) and corresponding image processing logic that processes the images to identify an estimated yield. The on-board system may include other types of perception systems as well, such as LIDAR, stereo cameras, etc. In another example, yield estimation system **160** can include a system that receives aerial images that are processed to generate normalized different vegetative index (NDVI) or leaf area index (LAI) at a particular growth stage, and uses one or more of those indices to estimate harvested yield. Yield estimation system **160** can also include real time yield sensors, which sense the current yield (such as the mass flow rate of grain through machine **100**, or other sensors indicative of yield) and correct the forward-looking yield estimates in the field, and particularly in the path over which machine **100** is traveling. These and other types of yield estimation systems are contemplated herein.

Error estimation system **162** illustratively estimates an error corresponding to the yield estimate generated by system **160**. In some examples, the error may be assumed to be 0%. In other examples, the error may be georeferenced and based on factors such as sensor signals, model outputs, or other sources of information used to predict or estimate the yield. It may also be based on factors such as the time since a last ground-truthed data collection was performed, historical differences between predicted and measured yield for this location, environmental conditions or other factors which may result in a difference between the estimated yield provided by system **160** and the actual measured yield at a particular location.

Where statistical techniques are used by yield estimation system **160** in order to generate an estimated yield value, then estimated error distributions may be determined along with the expected yield values. Where perception systems are used by yield estimation system **160**, then error may be estimated based on historic differences between the estimated and measured yields. The history may be from prior harvest at this or other locations, from the current harvesting operation or a combination of the two data sets. Environmental factors, such as obscurants (e.g. dust, rain, snow, etc.), lighting and crop stand attributes may also be used by error estimation system **162** in order to generate a georeferenced estimate of error corresponding to the yield estimate output by yield estimation system **160**.

Local material repository capacity **164** may be a value that is stored on harvesting machine **100**, itself. It is illustratively indicative of the overall capacity of the clean grain tank on machine **100**. It can also be a value that is stored at a remote location, and accessed by communication system **202** when harvesting machine **100** starts, or is about to start, its operation.

Position sensor **166** can be any of a wide variety of different types of position sensors such as a global positioning system (GPS) receiver, a dead reckoning system, or a wide variety of other systems that provide an indication of a current geographic location of harvesting machine **100**. They can provide orientation, ground speed and other information as well.

Current fill level sensor **170** illustratively senses a fill level in the local material repository (e.g., the clean grain tank) on harvesting machine **100**. It can be any of a wide variety of different level sensors, such as an optical sensor, a weight or mass sensor, a mass flow sensor that measures the amount of material entering clean grain tank **132** since it was last emptied, etc.

Yield and corresponding error map generation logic **168** illustratively generates a georeferenced yield estimate, along with a georeferenced error estimate. This is illustratively a georeferenced predicted yield map for at least a portion of the field over which harvester **100** is traveling, along with an error estimate corresponding to the georeferenced predicted yield. In one example, the georeferenced yield and corresponding error map is generated with a resolution that corresponds to segments along a travel path of harvesting machine **100**. For instance, where harvesting machine **100** harvests 12 rows at a time, then the georeferenced yield and corresponding error map will illustratively output estimated yield and error values for geographic locations that are 12 rows wide and a certain row length (e.g., 10 meters in linear row length). Of course, these values are examples only and the width of the path of harvesting machine **100**, and the length of the segments for which a yield and corresponding error is estimated can vary widely. In one example, they can be controlled or varied based on user inputs or otherwise. The yield and corresponding error map are output by logic **168** to path processing system **174**.

Remaining capacity identifier logic **172** illustratively generates a value indicative of a remaining capacity in the local material repository (e.g., the clean grain tank **132**) on harvesting machine **100**. This value is illustratively updated as machine **100** continues to operate, performing the harvesting operation and filling its clean grain tank.

Possible path generator logic **184** identifies a number of different, possible geographic paths of harvesting machine **100** through the field over which it is harvesting. In doing so, it illustratively takes into account the width of the harvesting head on machine **100**, crop that has already been harvested, the geographic location of any other harvesters or machines in the field, etc. It correlates the possible paths to the georeferenced yield and corresponding error map generated by logic **168**. Therefore, it identifies geographic locations or routes, on that map, that correspond to different paths that harvester **100** can take.

As is described in greater detail below, rendezvous point identifier logic **185** can identify different rendezvous points where harvester **100** can meet one or more haulage units in the field. This can be based on the location and fill status (full, empty, unloading, waiting to unload, etc.) of the haulage units, the location of harvester **100**, the speed of the vehicles, the routes, field terrain, etc. Uncertainty estimator **187** generates an uncertainty level corresponding to each rendezvous point. The uncertainty level accounts for various uncertainties in identifying the rendezvous points.

Cumulative yield per path identifier logic **186** identifies the cumulative yield that harvester **100** will encounter, as it travels over the different paths identified by logic **184**. For instance, it may be that the possible paths output by logic **184** have corresponding estimated yields, in 10-meter segments along the path. Therefore, as harvester **100** travels along a given path, the yield it has encountered will accumulate, with each harvested segment. Therefore, cumulative yield per path identifier logic **186** identifies the cumulative yield that will be encountered by harvester **100**, as it travels along each of the possible paths output by logic **184**.

Georeferenced probability distribution generator logic **188** then generates a georeferenced probability distribution indicative of the probability that the local material repository (e.g., the clean grain tank) will reach its capacity at different geographic locations along the field. It will do this for each path output by logic **184**, based upon the cumulative yield output by logic **186**.

Path surfacing interaction logic **190** then surfaces the various paths, along with the probability distributions, for user interaction. In one example, the user can select one of the paths and the machine **100** will be automatically controlled to follow that path. In another example, the operator can provide inputs to control machine **100** to travel along one of the paths. These and other operations can be performed, some of which are described in more detail below.

Measured yield identifier logic **192** measures the actual yield encountered by harvester **100**. This value can be fed back to yield estimation system **160**, or error estimation system **162** in order to correct the yield estimate, or the error estimate. These corrected values can then be used by logic **168** to generate an updated yield and corresponding error map.

Action threshold comparison logic **194** illustratively allows action thresholds to be set given the georeferenced probability distribution output by logic **188**. For instance, it may be that, if the probability that the clean grain tank is full exceeds a certain threshold, an alert may be generated using operator interface mechanisms **180** for operator **183**. Other action thresholds can be set and used to perform other operations as well, and some of them are described in more detail below.

Based on the various information generated by path processing system **174**, control signal generator **176** generates control signals that are applied to controllable subsystems **178**. For instance, control signal generator **176** can generate control signals to control propulsion subsystem **198** to control the speed of harvesting machine **100**. By way of example, if harvesting machine **100** is going to be full relatively quickly, but it will take a haulage unit a longer amount of time to reach it and unload it, then control signal generator **176** can control propulsion subsystem **198** to slow down harvesting machine **100**. This may reduce grain losses and it may increase the likelihood that the haulage unit will be able to travel to harvesting machine **100** before harvesting machine **100** has reached it capacity. In another example, if the georeferenced probability distribution indicates that, given the path harvesting machine **100** is taking, it will not be full before a haulage unit reaches it, then control signal generator **176** may generate control signals to control propulsion subsystem **198** to increase the speed of harvesting machine **100** so that it can harvest more crop, and be closer to its capacity, when a haulage unit reaches it. These are examples only.

Control signal generator **176** can also generate control signals to control steering subsystem **200**. For instance, it may be that operator **183** selects a possible path that is output by path processing system **174**. In that case, control signal generator **176** can control steering subsystem **200** to steer harvesting machine **100** along the selected path.

Control signal generator **176** can also control communication subsystem **202** to communicate various information within harvesting machine **100** or to one or more remote systems. The remote systems may be able to connect with communication subsystem **202** over a network, such as a cellular communication network, a wide area network, a local area network, a near field communication network, or a wide variety of other networks or combinations of networks.

Control signal generator **176** can also generate control signals to control operator interface logic **204**. The operator interface logic **204** can control operator interface mechanisms **180**, and receive operator interactions through those mechanisms. Operator interface mechanisms **180** may include such things as a steering wheel, joystick, levers, pedals, linkages, buttons, switches, and other such mechanisms. It can also include such things as a touch sensitive display screen so that user input mechanisms can be displayed, and actuated by operator **183**, using touch gestures. Mechanisms **180** can include a microphone and corresponding speech recognition system, as well as a speaker and corresponding speech synthesis system. Operator interface mechanisms **180** can include a wide variety of other mechanical, electromechanical, visual, audio or haptic systems as well. Those mentioned are mentioned for the sake of example only.

FIGS. **3**A and **3**B show a flow diagram illustrating one example of the operation of harvesting machine **100** in generating action signals based upon a georeferenced probability distribution indicating a georeferenced probability of the local material repository (e.g., clean grain tank **132**) on machine **100** reaching its capacity. It is first assumed that harvesting machine **100** and the worksite location (e.g., the field to be harvested) are identified. This is indicated by block **220** in the flow diagram of FIG. **3**. In one example, the information identifying the particular harvesting machine **100** also includes the local material repository capacity information **164**. It can include the geographic location of the field to be harvested, as indicated by block **222**, and it can include a wide variety of other things, as indicated by block **224**.

Yield and corresponding error map generation logic **168** then receives or obtains a predicted yield for at least one possible path of harvesting machine **100** at the worksite or field being harvested. This is indicated by block **226**. In one example, logic **168** outputs a georeferenced predicted yield map which identifies predicted yield at different geographical locations within the field. This is indicated by block **228**. It can be based on the yield estimate received from yield estimation system **160**.

Logic **168** can also output a georeferenced yield error estimate which identifies an estimate of error at the geographic locations within the field, for which the yield has been estimated. This can be based on the error estimate received from error estimation system **162**. Outputting the corresponding yield error estimate is indicated by block **230** in the flow diagram of FIG. **3**.

The georeferenced yield and corresponding error map can be output for at least one path (or possible path) of harvesting machine **100** through the field or worksite where it is harvesting. This is indicated by block **232**. It will be appreciated that it can be output for multiple different paths as well, or in other ways. This is indicated by block **234**.

Remaining capacity identifier logic **172** also receives a current fill level of the local material repository (e.g. the grain tank). This is indicated by block **236** in the flow diagram of FIG. **3**. This can be based on a sensor input **238** from current fill level sensor **170**, or it can be obtained in other ways, as indicated by block **240**. Remaining capacity identifier logic **172** then identifies the available capacity (or remaining capacity) in the local material repository (in the grain tank). This is indicated by block **238**. For instance, the current fill level (or measured amount) of material in the grain tank can be subtracted from the capacity of the repository to give the remaining capacity.

Possible path generator logic **184** identifies one or more different possibly paths of machine **100** through the field being harvested. It correlates those paths with the yield and corresponding error map generated by logic **168**. Cumulative yield per path identifier logic **186** then identifies the cumulative yield, for different sections along each of the identified paths. The cumulative high yield (given the expected yield plus an amount corresponding to the identified error) and the cumulative low yield (given the expected yield minus an amount corresponding to the estimated error) can be generated for each path as well. Generating a georeferenced estimate of yield is indicated by block **244**. Identifying the yield for different field segments is indicated by block **246** and identifying the corresponding error is indicated by block **248**. Identifying cumulative expected yield across different segments along one or more different possible paths for machine **100** is indicated by block **250**. Identifying the cumulative high and low yield values across those segments, based upon the estimated error value, is indicated by block **252**. The georeferenced estimate of yield can be generated in a wide variety of other ways as well, and this is indicated by block **254**.

Table 1 illustrates one example of this in more detail.

TABLE 1

Line	Value	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5
1	Estimated Yield (bu)	50.0	60.0	55.0	50.0	45.0
2	Estimated Yield Error	5%	8%	7%	8%	10%
3	-> Range High	52.5	64.8	58.8	54.0	49.5
4	-> Range Low	47.5	55.2	51.2	46.0	40.5
5	Cumulative High	52.5	117.3	175.8	229.8	279.3
6	Cumulative Mean	50.0	110.0	165.0	215.0	260
7	Cumulative Low	47.5	102.7	153.9	199.9	240.4
8	Capacity Risk Level	LOW	LOW	MED	HIGH	HIGH

Table 1 shows one example of information that can be generated in determining a georeferenced probability distribution indicative of where the grain tank **132** in machine **100** might reach its capacity. Table 1 shows the information for a single path of machine **100** that has been broken into five geographic segments along the path (e.g., along the field being harvester). The segments are identified as Seg1-Seg5 in Table 1 above.

Line 1 in Table 1 shows a value (in bushels) of the estimated or expected yield for each of the segments. This is illustratively the yield received from yield estimation system **160** and mapped to the different geographic locations by the yield and corresponding error map generator logic **168**. Line 2 in Table 1 shows the estimated error corresponding to each yield value. In the example shown in Table 1, the estimated yield error is the estimated 3–Σ error for a normal distribution. Lines 3 and 4 in Table 1 show the estimated high and low yield levels for each segment. For instance, line 3 shows a high yield value which includes the estimated yield from line 1 increased by the estimated error in line 2. Line 4 shows a value that is equal to the estimated yield in line 1 decreased by the estimated yield error.

Lines 5, 6 and 7 in Table 1 show the cumulative yield (in bushels) and specifically the cumulative high yield, the cumulative mean yield and the cumulative low yield, respectively. Thus, the cumulative high yield shown in line 5, for segment 2, is the sum of the high yield values from line 3, for segments 1 and 2. The cumulative value in line 5 for segment 3 is the sum of the values for segments 1, 2 and 3 from line 3.

Line 8 in Table 1 is an indicator that indicates the probability of the clean grain tank **132** on harvesting machine **100** reaching its capacity in each of the segments 1-5 shown in Table 1. The probabilities are divided into ranges identified by the values low, medium and high. For the sake of the example shown in Table 1, the probability that the grain tank of harvesting machine **100** will reach its capacity in any given segment is low if the available capacity for the grain tank on harvesting machine **100** is greater than the cumulative high value corresponding to that segment. For instance, in segment 1, it is assumed that the local material repository (e.g., the clean grain tank **132**) has a capacity of 300 bushels, and the current level in the grain tank is 130 bushels. The available capacity is thus 170 bushels. Therefore, the probability that the clean grain tank for machine **100** will reach its capacity in segment 1 is low because the available capacity of 170 bushels is greater than the cumulative high value of 52.5 bushels. The probability is the same in segment 2 because the available capacity of 170 bushels is still greater than the cumulative high of 117.3 bushels. However, in segment 3, it can be seen that the probability of the clean grain tank for harvesting machine **100** reaching its capacity is medium. This is because the cumulative mean shown in line 6 of Table 1 is less than the available capacity of 170 bushels, but the available capacity of 170 bushels is less than the cumulative high of 175.8 bushels shown for segment 3, in line 5 of Table 1.

The high probability range is defined by the available capacity being less than the cumulative mean. Therefore, segments 4 and 5 of the path represented by the information in Table 1 are assigned a high probability value because the available capacity of 170 bushels is less than the cumulative mean of 215 bushels and 260 bushels in segments 4 and 5, respectively. These representations of low, medium and high probability are examples only. Others can be used.

Generator logic **188** generates the georeferenced probability distribution of the local material repository becoming full, as shown in line 8 of Table 1, for example. For instance, it generates a probability distribution identifying different probabilities, at different geographic locations, where those probabilities are indicative of the probability that the grain tank on machine **100** will be full, at that particular geographic location. This is indicated by block **256** in the flow diagram of FIG. **3**. The probabilities can be raw numeric probabilities, or they can be divided into categories or thresholds (again, as shown in line 8 of Table 1). For instance, a low probability may be indicative of a geographic location where the available capacity in the grain tank of machine **100** is greater than the cumulative high yield (the estimated yield plus an amount indicated by the expected error). Setting a low threshold to this value is indicated by block **258** in the flow diagram of FIG. **3**.

A medium probability level may be indicated when the cumulative mean (e.g., that shown in line 6 of Table 1) is less than the available capacity, which is, itself, less than the cumulative high (the value shown in line 5 in Table 1). Defining a medium probability level in this way is indicated by block **260** in the flow diagram of FIG. **3**.

A high probability level may be defined where the available capacity of the grain tank in machine **100** is less than the cumulative mean shown in line 6 of Table 1 above. Defining the high probability category in this way is indicated by block **262**. The georeferenced probability distribution can be identified in other ways as well. This is indicated by block **264**.

Path surfacing/interaction logic **190** then illustratively correlates the georeferenced probability distribution to a current position of the harvesting machine. This is indicated by block **266** in the flow diagram of FIG. **3**. The current geographic location of machine **100** can be obtained from position sensor **166**, or otherwise. Path surfacing/interaction logic **190** can receive other information as well, such as possible rendezvous points where hauling units may rendezvous with machine **100**, to unload it. This is indicated by block **268** in the flow diagram of FIG. **3**, and it is described in greater detail below with respect to FIGS. **4** and **4**A. The georeferenced probability distribution can be correlated to the current position of machine **100** in other ways as well, and this is indicated by block **269**.

FIG. **3**C is one example of a user interface display **270** that can be used to surface information such as that shown in Table 1. Display **270** shows the position of machine **100**, and its direction of travel, with an icon or other graphical representation **272**. It is making a current pass through the field. FIG. **3** shows that a portion of the field being harvested has been divided into segments. Each segment is in a current pass, or one of three different optional passes that the machine can take after it makes a turn in the headland area graphically represented by area **274**. Each cell on the display **270** represents a segment in the field. The letter in each cell represents the corresponding probability value, indicative of the probability that the clean grain tank **132** on machine **100** will be full, in that segment. Therefore, it can be seen in FIG. **3**C that the machine can finish its first pass and reach the headland area **274**, for a headland turn, without the probability that its grain tank **132** will reach its capacity exceeding the low level. Then, however, once the machine makes a headland turn, it can choose one of three different path options. It can be seen with the path option 1 that the machine can make a turn and continue harvesting all the way to segment **276** in the field represented by the display, before the probability that its grain tank will reach its capacity moves from the low probability level to the medium probability level. It can continue harvesting until it reaches segment **278** before that value moves to a high probability value.

However, if the machine takes path option 2, it can only harvest to segment **280** before the probability that its clean grain tank **132** will reach its capacity will switch from a low to a medium probability level. At segment **282**, the probability goes to a high probability level.

With path option 3, the machine can harvest until it reaches field segment **284** before the probability reaches a medium value. It can harvest until it reaches field segment **286** before the probability that its grain tank **132** will reach its capacity changes to a high probability value.

Returning again to the flow diagram shown in FIG. **3**, action threshold comparison logic **194** compares a current probability (or other value) to various action thresholds, some examples of which were described above as possibility values low, medium and high. When the value reaches an action threshold, then certain actions may be taken.

It will be noted that the action thresholds can be a wide variety of different thresholds, based upon a wide variety of different criteria. For instance, a threshold may be set that indicates a certain distance that the machine **100** is from a field segment where the probability value will change values. For instance, and again referring to FIG. **3**C, assume that an action threshold has been set to indicate when the machine is less than five segments away from a field segment where the probability value changes. By way of example, assume that the distance threshold is set to five segments. Assume further that the operator of the machine takes a headland turn and begins to harvest along path option 1 in FIG. **3**C. Then, when the harvester reaches the field segment **290**, action threshold comparison logic **194** may be triggered to take some action, because the machine is now within 5 field segments of its probability value changing from low to medium.

The thresholds can take a wide variety of other forms as well. For instance, the threshold may be set to a value corresponding to a point where the probability value actually does change. That threshold would be met, for example, when machine **100** moves from a field segment corresponding to probability value of low to an adjacent field segment corresponding to a probability value of medium or, where it moves from a field segment corresponding to a probability value of medium to an adjacent field segment where the corresponding probability value is high. The threshold can be set to identify a certain distance from a headland turn (so that the operator has adequate opportunity to select his or her next pass through the field), or it can be set based on time, such as a certain time before the probability that its grain tank is full moves to a next highest probability value. The threshold can be set in a wide variety of other ways as well. Determining whether an action threshold has been reached is indicated by block **292** in the flow diagram of FIG. **3**.

When an action threshold has been reached, action threshold comparison logic **194** indicates this to control signal generator **176**. Control signal generator **176** then generates one or more control signals to control one or more controllable subsystems **178** based upon the particular action threshold that has been reached. Generating control signals under these circumstances is indicated by block **294** in the flow diagram of FIG. **3**.

Control signal generator **176** can generator control signals in a wide variety of different ways. For instance, it can generate different control signals based upon a variety of different action thresholds and desired responses. This is indicated by block **296**. By way of example, if the harvesting machine **100** has entered a segment where the probability that its grain tank will reach its capacity is high, then control signal generator **176** may generate a control signal to control operator interface logic **204** to sound an alarm or to otherwise generate an alarm output for operator **183**. Or, under those circumstances, control signal generator **176** may generate a control signal to control propulsion subsystem **198** to stop harvesting machine **100** so that the grain tank does not overflow, or to wait for a haulage unit, or to wait until operator **183** overrides that command. However, if the machine **100** has entered a segment where the probability has raised from low to medium, then a display may be generated, but without an alarm. Similarly, if harvester **100** is in a segment where the probability is low, then control signal generator **176** may control the controllable subsystems **178** so that a simple display is generated, or so that no display is generated.

Control signal generator **176** may control steering subsystem **200** to steer machine **100** based upon the action threshold that was crossed. For instance, if a haulage unit is currently available, or will soon be available, to unload machine **100**, then control signal generator **176** may generate steering control signals to control steering subsystem **200** so that the machine **100** takes machine path 2 shown in FIG. **3**C. However, if a haulage unit is not presently available, and may not be available for some time, then control signal generator **176** may generate control signals to control steering subsystem **200** to take path option 1 shown in FIG. **3**C. This will delay the time when the clean grain tank on machine **100** will likely be full. This will give the haulage unit time to reach machine **100**. Controlling the steering actuator, or steering subsystem **200** is indicated by block **298** in the flow diagram of FIG. **3**.

Where the action threshold indicates a distance or time from a position where the probability value will increase, then control signal generator **176** may control propulsion subsystem **198** to decrease the speed, or to increase the speed of machine **100**. For instance, if the estimated yield values for a certain portion of the field have fallen, this may indicate that machine **100** can increase its speed, because the next field segment where the probability that its grain tank will be full increases is a relatively large distance from its current location. Similarly, if the yield has increased, then control signal generator **176** may generate control signals to control propulsion subsystem **198** to reduce the speed of machine **100**, so that the time before its grain tank is likely going to be at is capacity is increased. This may be done in order to give a haulage unit extra time to reach machine **100** so that machine **100** can continue harvesting, without stopping and remaining idle to wait for a haulage unit. Controlling the speed actuator or propulsion subsystem is indicated by block **300** in the flow diagram of FIG. **3**.

Control signal generator **176** can control operator interface logic **204** to control various operator interface mechanisms **180**. As discussed above, this can include generating a display (such as that shown in FIG. **3**C), generating an alarm, generating audible, visual, or haptic outputs, as well as receiving operator inputs through operator interface mechanisms **180**. Generating control signals to control operator interface logic **204** and operator interface mechanisms **180** is indicated by block **302** in the flow diagram of FIG. **3**.

Control signal generator **176** can also generate control signals to control communication subsystem **202**. This is indicated by block **304** in the flow diagram of FIG. **3**. For instance, it may be that machine **100** has crossed the threshold to indicate that it is now in a field segment where it is highly probable that its grain tank will reach capacity. In that case, control signal generator **176** can automatically generate control signals to control communication subsystem **202** to send a message to a haulage unit (such as the driver of a tractor pulling one or more grain carts) that machine **100** is about to have a full grain tank. It can control communication subsystem **202** to communicate with a site manager or farm manager or with a semi-driver, or with other remote machines and people as well.

Control signal generator **176** can also illustratively generate control signals that are communicated using communication subsystem **202** to communicate with or control other machines. For instance, the control signals may generate a display or other alert in the operator compartment of a haulage unit indicating that the harvester needs haulage attention. It can provide a most direct route (or an otherwise preferred route) from the haulage unit's current location to the location of machine **100**. It can automatically control the haulage unit to follow that route. By automatic it is meant that the operation or function can be carried out without further operator involvement except, perhaps, to authorize or initiate the function. Controlling and communicating with other machines is indicated by block **306** in the flow diagram of FIG. **3**. Control signal generator **176** can generate a wide variety of other control signals, based upon the action threshold that has been reached. This is indicated by block **308**.

In one example, this type of operation continues on machine **100** until the harvesting operation is complete, as indicated by block **310**. If the harvesting operation is not complete, then the harvester may wait for a pre-determined time period, or may travel a specified distance, or may wait for other criteria to occur, and then return to processing at block **226**, where information is received or obtained in order to update the georeferenced probability distribution map. This is indicated by block **312**.

FIG. **4** is a flow diagram showing one example of the operation of machine **100** and path processing system **174** in not only identifying a plurality of different possible paths of machine **100** through a field, and the corresponding georeferenced probability distribution, but also identifying potential rendezvous points where a haulage unit (such as a tractor pulling one or more grain carts) may rendezvous with machine **100** to unload it. Control signal generator **176** first controls communication subsystem **202** to identify the locations of any support vehicles that are supporting harvester **100** in the field being harvested. This is indicated by block **314** in the flow diagram of FIG. **4**. It can identify the positions, for instance, of various different haulage units (tractor/grain cart combinations). This is indicated by block **316**. It can identify the location of a semi or other transport truck as indicated by block **318**, and it can identify the locations of any of a wide variety of other vehicles. This is indicated by block **320**.

FIG. **4**A shows one example of a user interface display **322** indicating some of these items. User interface display **322** has some items that are similar to the user interface display **270**, shown in FIG. **3**C, and similar items are similarly numbered. However, it can be seen in FIG. **4**A that display **322** also shows a position of a semi-truck **324**, a first haulage unit or haulage vehicle **326** and the position of a second haulage unit or haulage vehicle **328**. In one example, the locations of vehicles **324**-**328** are shown relative to the icon **272** representing harvester **100**. Also, the graphical illustrations of vehicles **326** and **328** may indicate their status (such as whether they are full, or empty). By way of example, the lowercase letters identified on haulage vehicle **326** ("hv**1**") may indicate that it is empty. The uppercase letters on haulage vehicle ("HV**2**") may indicate that it is full. The fill statuses can be indicated in a wide variety of other ways as well.

Control signal generator **176** may control communication subsystem **202** to receive or obtain other information, such as timing and other parameter information from the various vehicles. This is indicated by block **330** in the flow diagram of FIG. **4**. For instance, it may receive an indication from vehicles **326** and/or **328** indicating an unload time, which identifies a time that will be needed for the vehicle to unload its grain into semi **324** or elsewhere (which may be based on historic values or an estimate, knowing the size of the cart, the characteristics of the unloading mechanism, etc.). This is indicated by block **332**. It may receive information indicative of the travel speed of vehicles **326** and **328**, which may indicate how long it will take those vehicles to reach semi **324** and to return to the various locations on the field being harvested by harvester **100**. Receiving an indication of the travel speed is indicated by block **334** in FIG. **4**. The communication subsystem **202** may be controlled to receive information indicative of the fuel consumption of haulage units or vehicles **326** and **328**. This may be the rate of fuel consumption, estimated fuel consumption to reach a location (such as to travel to semi **324** and back to various locations) on the field being harvested by harvester **100**, or other information. Receiving fuel consumption parameters is indicated by block **336** in the flow diagram of FIG. **4**. Communication subsystem **202** can receive a wide variety of other timing information or parameters as well. This is indicated by block **338**.

Rendezvous point identifier logic **185** identifies likely rendezvous points for vehicles **326** and **328** with harvester **100**. This is indicated by block **340** in the flow diagram of FIG. **4**. The likely rendezvous points are determined based upon the location of the vehicles and the various timing and parameter information received at block **330**. By way of example, in the user interface display illustrated in FIG. **4**A, the "1" indicates where haulage vehicle hv1 (**326**) will be able to meet harvester **100** in the corresponding path. For instance, if harvester **100** makes a headland turn in headland area **274** and chooses to harvest along path option 1, the haulage vehicle **1** (**326**) can rendezvous with harvester **100** in field segment **342**. This means that rendezvous point identifier logic **185** has calculated that haulage vehicle hv**1** (**326**) can finish unloading at semi **324**, travel to the headland area **274** in the left of the field being harvested, and then catch up to harvesting machine **100** (as it is traveling left to right along path option 1 in the field) at field segment **344**. Similarly, if machine **100** chooses path option 2, then haulage vehicle **1** (**326**) will catch up to it at field segment **344**. If harvester **100** begins harvesting in path option 3, then haulage vehicle **1** (**326**) will catch up to it at field segment **346**.

By contrast, haulage vehicle **2** (**328**) needs to travel all the way back to semi **324**, and unload before it is available to travel back to the harvester **100**. Therefore, it is not able to rendezvous with harvester **100** until harvester **100** reaches field segment **348** (in path option 1), field segment **350** (in path option 2) and field segment **352** (in path option 3).

Uncertainty estimator **187** may identify rendezvous points **342**-**352** with an estimated uncertainty level. The uncertainty may be influenced by the topography of the field, by the certainty with which logic **185** knows the estimated speed at which the vehicle will be traveling, the weather, the soil conditions, among other things. Therefore, it may be that display **322** displays the rendezvous points (e.g., the "1" and "2") in varying colors indicative of how certain the rendezvous points are to be correct. For instance, if they are displayed in red, this may indicate a lowest probability that the rendezvous point is correct (or lowest confidence) whereas if they are displayed in green, this may indicate a highest probability that the rendezvous points are correct (or highest confidence).

Once the rendezvous points are identified, then control signal generator **176** illustratively generates control signals based upon the likely rendezvous points. This is indicated by block **354** in the flow diagram of FIG. **4**. By way of example, control signal generator **176** can generate control signals to perform automatic selection of a particular path option, and control machine **100** to move along that path option. This is indicated by block **356**. For instance, it may be that control signal generator **176** generates control signals to control propulsion subsystem **198** and steering subsystem **200** to control machine **100** to travel along path option 3, because it is most likely that haulage vehicle **1** (**326**) will be able to receive grain from machine **100** before it is full. In another example, however, it may be that control signal generator **176** controls propulsion subsystem **198** and steering subsystem **200** to control machine **100** to take path option 1 because that is the path that allows machine **100** to get as full as possible before the haulage vehicle arrives. Control signal generator **176** can control propulsion subsystem **198** and steering subsystem **200** to cause combine **100** to select a next pass after reaching headland area **274** based on different criteria. In one example, it may select the next pass as the one with the earliest fill point (e.g., where the georeferenced probability distribution indicates that the combine will likely reach its fill capacity earliest in the pass). In another example, it may choose the pass with the latest fill point. It may choose the pass that has a best rendezvous with a moving haulage vehicle (e.g., where the haulage vehicle is most likely to reach harvester **100** before its grain tank is full). It may also choose a pass where the most likely fill point is closest to a fixed haulage vehicle (e.g., where it is closest to a truck parked in the headlands area **274** or elsewhere). These and other examples as well as other criteria are contemplated herein.

In another example, control signal generator **176** can control operator interface logic **204** to surface the path options and corresponding rendezvous points on an operator interface mechanism **180** for interaction by operator **183**. As is shown in the example illustrated in FIG. **4**A, each of the path options 1-3 may be actuatable so that operator **183** can select one of the path options by simply tapping on that actuator. If the user taps on the actuator, then control signal generator **176** detects this and generates control signals to again control the propulsion subsystem **198** and steering subsystem **200** to control machine **100** to travel down the selected path option. Surfacing the options on an operator interface is indicated by block **358** in the flow diagram of FIG. **4**, and detecting operator selection of one of the options is indicated by block **360**. Automatically controlling the vehicle based upon the selected path option is indicated by block **362**. The path option can be selected in other ways as well, such as using a voice command, a point and click device, or in other ways.

It will also be noted that, in one example, control signal generator **176** can generate control signals to control communication subsystem **202** to communicate the rendezvous points to other vehicles. This is indicated by block **364** in the flow diagram of FIG. **4**. By way of example, it may be that communication subsystem **202** is controlled to communicate the geographic location of a desired rendezvous point to haulage vehicle **1** (**326**) so that its operator can move to that rendezvous point as quickly as possible. It may be that the rendezvous point can be communicated to the navigation system in the haulage vehicle so that it automatically proceeds to the rendezvous point on the path option selected by the operator **183** or harvester **100**.

Control signal generator **176** can generate control signals to controllable subsystems **178** in a wide variety of other ways as well. This is indicated by block **366**.

FIG. **5** illustrates one example of path processing system **174**. Path processing system **174** includes an obstacle avoidance system **400** that illustratively includes obstacle detection logic **402**, obstacle boundary generation logic **404**, obstacle avoidance logic **406**, and unload path determination logic **408**. System **400** can include other items **409** as well. Path processing system **174** is also illustrated as having one or more processors **410**.

Operation of obstacle avoidance system **400** is discussed in further detail below. Briefly, system **400** is configured to identify obstacles in a field that are likely to hinder operation of harvester machine **100** during a harvesting operation and/or during unloading of machine **100** into a haulage unit or vehicle. System **400** is configured to generate obstacle boundaries corresponding to such obstacles, and to perform obstacle avoidance by controlling machine **100** and/or the haulage units to avoid the obstacles during their operation. In one example, the rendezvous point for the haulage unit and machine **100** is selected based on a determined fill probability of machine **100** (e.g., the georeferenced probability distribution) and the obstacle boundaries. Alternatively, or in addition, a corresponding unloading path to be used by machine **100** and a haulage unit while machine **100** is being unloaded "on-the-go" is determined based on the obstacle boundaries.

Obstacle detection logic **402** is configured to detect obstacles in a field under consideration (e.g., a field on which machine **100** is performing a harvesting operation). Examples include, but are not limited to, obstacles related to terrain topology, terrain (e.g., soil) condition, and non-terrain obstacles. For instance, terrain topology-related obstacles include areas of terrain having a slope above a threshold, the edge or boundary of the field (e.g., a fence line, roadway, etc.), to name a few. Examples of terrain condition-related obstacles include indications of soil type or condition (e.g., saturated soil or areas of terrain that are under water), to name a few. Non-terrain obstacles can include obstructions such as poles or power lines on or along the field.

FIG. **6** illustrates one example of a method **412** of operating an agricultural harvesting machine. For sake of illustration, but not by limitation, method **412** will be described in the context of path processing system **174** shown in FIG. **5**.

At block **414**, the method determines the fill capacity of a harvested crop repository. One example is described above with respect to block **220** in FIG. **3**A in which the capacity of the grain tank on the harvester is determined based on identification of the harvesting machine. The determined fill capacity can be the maximum fill capacity of the machine, or a percentage thereof.

At block **416**, a predicted crop yield at a plurality of different field segments is obtained. In one example, block **416** is similar to block **226** discussed above with respect to FIG. **3**A.

In one example, the predicted crop yield obtained at block **416** is based on a priori data, and is used to generate a predictive map. The a priori data can be obtained in a variety of ways, such as from optical images of the field, forward of the harvester in the direction of travel. This can be obtained from on-board cameras or other imaging components on the harvester itself. Alternatively, or in addition, it can be obtained from aerial images, such as images obtained from unmanned aerial vehicles (UAVs) and/or satellite imagery.

Alternatively, or in addition, the predicted crop yield obtained at block **416** can be based on historical yield data for the field segments. For instance, yield data from a prior year's harvest can be utilized to predict the crop yield in those field segments. This historical yield data can be stored on machine **100**, obtained from a remote system, or otherwise obtained by path processing system **174**. Further, it can be combined with the a priori data obtained from images of the field.

At block **418**, the crop is processed into the harvested crop repository. At block **420**, field data corresponding to one or more of the field segments is obtained. Illustratively, this includes obtaining actual yield data at block **422**. That is, as machine **100** is performing the harvesting operation, sensors on the harvester generate in situ data (or field data) indicative of the various sensed variables, during the operation. Here, the in situ data is actual yield data generated from yield sensors. In one example, yield sensors include on-board mass flow sensors that sense the mass of flow of grain (or other crop) entering the clean grain tank on machine **100**. That mass flow can then be correlated to a geographic position in the field from which it was harvested, to obtain an actual yield value for that geographic position (e.g., the field segment). Of course, the field data can be obtained at block **420** in other ways as well.

At block **424**, a yield correction factor is generated based on the predicted crop yield obtained at block **416** and the field data obtained at block **420**. Illustratively, the yield correction factor represents an error between the predicted crop yield (i.e., generated from previously collected data from a prior year's harvest, earlier or real-time collected image data from a satellites or drone, and/or other a priori data) and the actual yield data collected from on-board sensor. For example, the yield correction factor is calculated based on a difference between the predicted crop yield and the actual crop yield. This is represented by block **426**. Further, a yield correction factor can be generated individually for each field segment, and then the individual yield correction factors averaged, or otherwise combined, to obtain an overall yield correction factor.

At block **428**, the current fill level of the harvested crop repository is determined. One example is discussed above with respect to block **236** in FIG. **3**A. For instance, a sensor input is received from a current fill level sensor **170**, or it can be obtained in other ways. In one example, the available capacity (or remaining capacity) in the repository is determined by remaining capacity identifier logic **172**.

At block **430**, a geo-referenced probability metric indicative of a probability of the repository becoming full is generated. In the illustrated example, this includes applying the yield correction factor, generated at block **424**, to the predicted yield, to obtain a corrected, predicted crop yield. This is represented by block **432**.

In one example, the corrected, predicted crop yield is identified for a plurality of different field segments in a path of the harvester. The corrected, predicted crop yield is determined by correcting the predicted crop yield for a field segment (obtained at block **416**) with the yield correction factor (generated at block **424**). Then, a cumulative expected yield across a field segment, or set of segments, in a path of the harvester is determined. One example of generating a geo-referenced probability distribution, and correlating such a distribution to a position of the machine, is discussed above with respect to blocks **256** and **266**.

The harvesting machine **100** and/or other support machines (such as haulage vehicles) can be controlled based on the probability metric. One example of generating control signals is discussed above with respect to block **294**.

In one example, operator interface mechanisms **180** are controlled to render an indication of the current fill level of the harvested crop repository, a remaining capacity of the repository, and/or a predicted time (and/or distance) until the repository is full and requires unloading. For instance, a countdown timer can be rendered to operator **183** and/or to other users. For instance, communication subsystem **202** can be controlled to communicate with a user associated with a haulage vehicle, to provide an indication of the fill level, remaining fill capacity, predicted time to fill capacity, and/or rendezvous path or point information. In another example, a haulage vehicle can be automatically controlled for the unloading operation.

In the illustrated example, at block **434**, obstacle detection and avoidance is performed during an unloading operation in which the harvested crop repository of machine **100** is unloaded into a haulage vehicle or other support machine.

FIG. **7** illustrates one example of a method **440** for performing obstacle detection and avoidance. For sake of illustration, but not by limitation, method **440** will be described in the context of obstacle avoidance system **400** shown in FIG. **5**.

At block **442**, field data is received. This can include terrain topology information (represented by block **444**), terrain conditions (represented by block **446**), and can include other data (represented by block **448**). In one example, terrain topology information represents topology characteristics, such as slope information, field boundaries, non-crop acres, trees, etc. The terrain topology information can be obtained from terrain maps retrieved from a local data store, a remote system, or otherwise.

Examples of terrain conditions include, but are not limited to, soil characteristics and conditions. This can include soil moisture information indicative of standing water, muddy soil, or other conditions that may adversely impact machine traversal or other operation across an area of terrain. This can be obtained in any of a variety of ways such as, but not limited to, soil moisture sensors.

At block **450**, a set of obstacles are identified based on the received field data at block **442**. In one example, this includes comparing the field data to threshold obstacle criteria. In one example, this can include threshold terrain slope, threshold soil moisture, threshold soil type, to name a few.

At block **452**, obstacle boundaries are generated based on the obstacles identified at block **450**. This can include generating a field map with the obstacle boundaries at block **454**. Illustratively, the obstacle boundaries identify areas of the field to be avoided during the unloading operation to unload the harvested crop repository of machine **100** to a haulage vehicle.

Additionally, the predicted and/or actual crop yield data can be utilized in generating the obstacle boundaries and path of harvester **100** during the harvesting operation and unloading into a haulage vehicle. For example, a predicted weight of harvester **100** at the different field segments can be determined based on the predicted crop yield data. Then, the predicted weight of harvester **100** can be utilized in conjunction with the terrain conditions (e.g., soil moisture, terrain slope, etc.) to identify areas to be avoided for any of a variety of reasons, such as, but not limited to, preventing the creation of ruts or ground compaction, preventing machine **100** from becoming stuck, etc. Similarly, the weight of a haulage vehicle before, during, and/or after unloading of harvester **100** can be determined and utilized to identify the obstacle boundaries.

Based on the obstacle boundaries, a rendezvous point or path is determined for the unloading operation. This is represented by block **456**. This can include a stationary unloading operation in which machine **100** is stopped while the repository is unloaded into a haulage vehicle. This is represented by block **458**. In another example, the unloading operation can be performed "on-the-go". This is represented by block **460**. In one example, machine **100** continues to traverse across the field and perform further harvesting operations while the repository is unloaded into a haulage vehicle that is moved at a same speed alongside machine **100**. In this case, a rendezvous path is generated that defines a traversal path across the field that is based on a start point for the unloading operation and an expected time duration for unloading the harvested crop into the haulage vehicle. In either case, the rendezvous point for the stationary unloading operation at block **458** or the starting point of the "on-the-go" unloading operation at block **460** is determined at block **456** based on the probability metric indicative of the probability of the repository becoming full at various segments in the field and the obstacle boundaries generated at block **452**.

At block **462**, a control signal is generated based on the rendezvous or path. This can be used to control machine **100** at block **464**, control the haulage vehicle at block **466**, or otherwise at block **468**.

FIG. **8** illustrates one example of determining a rendezvous point and unloading path for a harvesting machine. As shown in FIG. **8**, machine **100** is making a current pass through field **470**. Path processing system **174** has identified probability levels, indicative of a probability of the harvested crop repository of machine **100** becoming full, at each of a plurality of field segments **472**. A haulage vehicle **474** is configured to rendezvous with machine **100** and perform an "on-the-go" unloading operation.

Further, a set of obstacle boundaries have been identified based on obstacles identified on field **470**. Field segments that reside within the obstacle boundaries are illustrated by cross hatching in FIG. **8**. Illustratively, a set of field segments **476** reside within at least one of the obstacle boundaries. For example, but not by limitation, segments **476** may be determined to have (or are likely to have) standing water, muddy conditions, and/or a slope above a threshold, which may adversely affect the unloading operation to unload the harvested crop from machine **100** into haulage vehicle **474**.

Based on the probability levels associated with the field segments, and an estimated duration for the unloading operation, path processing system **174** identifies field segment **478** as a rendezvous point for haulage vehicle **474**. Accordingly, it is determined that the unloading operation can begin at field segment **478** and can continue along a portion of the path represented by arrow **480**, and will complete before machine **100** and/or haulage vehicle **474** enter one of the obstacle boundaries. Therefore, the unloading operation can begin even though the repository is partially full (e.g., 75%, etc.), but results in the unloading operation avoiding traversal in, through, or around an obstacle.

While the present discussion has proceeded with respect to a harvester, it can be used with other machines that collect or distribute material as well. Where the machine distributes material, the description is similar except that instead of generating a georeferenced possibility distribution of where the material repository will be full, it will represent the probability distribution of where the material repository will be empty.

The present discussion has mentioned processors and servers. In one example, the processors and servers include computer processors with associated memory and timing circuitry, not separately shown. They are functional parts of the systems or devices to which they belong and are activated by, and facilitate the functionality of the other components or items in those systems.

It will be noted that the above discussion has described a variety of different systems, components and/or logic. It will be appreciated that such systems, components and/or logic can be comprised of hardware items (such as processors and associated memory, or other processing components, some of which are described below) that perform the functions associated with those systems, components and/or logic. In addition, the systems, components and/or logic can be comprised of software that is loaded into a memory and is subsequently executed by a processor or server, or other computing component, as described below. The systems, components and/or logic can also be comprised of different combinations of hardware, software, firmware, etc., some examples of which are described below. These are only some examples of different structures that can be used to form the systems, components and/or logic described above. Other structures can be used as well.

Also, a number of user interface displays have been discussed. They can take a wide variety of different forms and can have a wide variety of different user actuatable input mechanisms disposed thereon. For instance, the user actuatable input mechanisms can be text boxes, check boxes, icons, links, drop-down menus, search boxes, etc. They can also be actuated in a wide variety of different ways. For instance, they can be actuated using a point and click device (such as a track ball or mouse). They can be actuated using hardware buttons, switches, a joystick or keyboard, thumb switches or thumb pads, etc. They can also be actuated using a virtual keyboard or other virtual actuators. In addition, where the screen on which they are displayed is a touch sensitive screen, they can be actuated using touch gestures. Also, where the device that displays them has speech recognition components, they can be actuated using speech commands.

A number of data stores have also been discussed. It will be noted they can each be broken into multiple data stores. All can be local to the systems accessing them, all can be remote, or some can be local while others are remote. All of these configurations are contemplated herein.

Also, the figures show a number of blocks with functionality ascribed to each block. It will be noted that fewer blocks can be used so the functionality is performed by fewer components. Also, more blocks can be used with the functionality distributed among more components.

FIG. **9** is a block diagram of harvester **100**, shown in FIG. **2**, except that it communicates with elements in a remote server architecture **500**. In an example embodiment, remote server architecture **500** can provide computation, software, data access, and storage services that do not require end-user knowledge of the physical location or configuration of the system that delivers the services. In various embodiments, remote servers can deliver the services over a wide area network, such as the internet, using appropriate protocols. For instance, remote servers can deliver applications over a wide area network and they can be accessed through a web browser or any other computing component. Software or components shown in FIG. **2** as well as the corresponding data, can be stored on servers at a remote location. The computing resources in a remote server environment can be consolidated at a remote data center location or they can be dispersed. Remote server infrastructures can deliver services through shared data centers, even though they appear as a single point of access for the user. Thus, the components and functions described herein can be provided from a remote server at a remote location using a remote server architecture. Alternatively, they can be provided from a conventional server, or they can be installed on client devices directly, or in other ways.

In the example shown in FIG. **9**, some items are similar to those shown in FIG. **2** and they are similarly numbered. FIG. **9** specifically shows that path processing system **174**, yield estimation system **160** and error estimation system **162** can be located at a remote server location **502**. Therefore, harvester **100** accesses those systems through remote server location **502**.

FIG. **9** also depicts another example of a remote server architecture. FIG. **9** shows that it is also contemplated that some elements of FIG. **2** are disposed at remote server location **502** while others are not. By way of example, field estimation system **160** or other systems or logic can be disposed at a location separate from location **502**, and accessed through the remote server at location **502**. Regardless of where they are located, they can be accessed directly by harvester **100**, through a network (either a wide area network or a local area network), they can be hosted at a remote site by a service, or they can be provided as a service, or accessed by a connection service that resides in a remote location. Also, the data can be stored in substantially any location and intermittently accessed by, or forwarded to, interested parties. For instance, physical carriers can be used instead of, or in addition to, electromagnetic wave carriers. In such an embodiment, where cell coverage is poor or nonexistent, another mobile machine (such as a fuel truck) can have an automated information collection system. As the harvester comes close to the fuel truck for fueling, the system automatically collects the information from the harvester using any type of ad-hoc wireless connection. The collected information can then be forwarded to the main network as the fuel truck reaches a location where there is cellular coverage (or other wireless coverage). For instance, the fuel truck may enter a covered location when traveling to fuel other machines or when at a main fuel storage location. All of these architectures are contemplated herein. Further, the information can be stored on the harvester until the harvester enters a covered location. The harvester, itself, can then send the information to the main network.

It will also be noted that the elements of FIG. **2**, or portions of them, can be disposed on a wide variety of different devices. Some of those devices include servers, desktop computers, laptop computers, tablet computers, or other mobile devices, such as palm top computers, cell phones, smart phones, multimedia players, personal digital assistants, etc.

FIG. **10** is a simplified block diagram of one illustrative embodiment of a handheld or mobile computing device that can be used as a user's or client's hand held device **16**, in which the present system (or parts of it) can be deployed. For instance, a mobile device can be deployed in the operator compartment of harvester **100** for use in generating, processing, or displaying the yield estimation data, path processing data, and/or obstacle avoidance data. FIGS. **11-12** are examples of handheld or mobile devices.

FIG. **10** provides a general block diagram of the components of a client device **16** that can run some components shown in FIG. **2**, that interacts with them, or both. In the device **16**, a communications link **13** is provided that allows the handheld device to communicate with other computing devices and under some embodiments provides a channel for receiving information automatically, such as by scanning. Examples of communications link **13** include allowing communication though one or more communication protocols, such as wireless services used to provide cellular access to a network, as well as protocols that provide local wireless connections to networks.

In other examples, applications can be received on a removable Secure Digital (SD) card that is connected to an interface **15**. Interface **15** and communication links **13** communicate with a processor **17** (which can also embody processors from previous FIGS.) along a bus **19** that is also connected to memory **21** and input/output (I/O) components **23**, as well as clock **25** and location system **27**.

I/O components **23**, in one embodiment, are provided to facilitate input and output operations. I/O components **23** for various embodiments of the device **16** can include input components such as buttons, touch sensors, optical sensors, microphones, touch screens, proximity sensors, accelerometers, orientation sensors and output components such as a display device, a speaker, and or a printer port. Other I/O components **23** can be used as well.

Clock **25** illustratively comprises a real time clock component that outputs a time and date. It can also, illustratively, provide timing functions for processor **17**.

Location system **27** illustratively includes a component that outputs a current geographical location of device **16**. This can include, for instance, a global positioning system (GPS) receiver, a LORAN system, a dead reckoning system, a cellular triangulation system, or other positioning system. It can also include, for example, mapping software or navigation software that generates desired maps, navigation routes and other geographic functions.

Memory **21** stores operating system **29**, network settings **31**, applications **33**, application configuration settings **35**, data store **37**, communication drivers **39**, and communication configuration settings **41**. Memory **21** can include all types of tangible volatile and non-volatile computer-readable memory devices. It can also include computer storage media (described below). Memory **21** stores computer readable instructions that, when executed by processor **17**, cause the processor to perform computer-implemented steps or functions according to the instructions. Processor **17** can be activated by other components to facilitate their functionality as well.

FIG. **11** shows one example in which device **16** is a tablet computer **600**. In FIG. **11**, computer **600** is shown with user interface display screen **602**. Screen **602** can be a touch screen or a pen-enabled interface that receives inputs from a pen or stylus. It can also use an on-screen virtual keyboard. Of course, it might also be attached to a keyboard or other user input device through a suitable attachment mechanism, such as a wireless link or USB port, for instance. Computer **600** can also illustratively receive voice inputs as well.

FIG. **12** shows that the device can be a smart phone **71**. Smart phone **71** has a touch sensitive display **73** that displays icons or tiles or other user input mechanisms **75**. Mechanisms **75** can be used by a user to run applications, make calls, perform data transfer operations, etc. In general, smart phone **71** is built on a mobile operating system and offers more advanced computing capability and connectivity than a feature phone.

Note that other forms of the devices **16** are possible.

FIG. **13** is one example of a computing environment in which elements of FIG. **2**, or parts of it, (for example) can be deployed. With reference to FIG. **13**, an example system for implementing some embodiments includes a general-purpose computing device in the form of a computer **810**. Components of computer **810** may include, but are not limited to, a processing unit **820** (which can comprise processors from pervious FIGS.), a system memory **830**, and a system bus **821** that couples various system components including the system memory to the processing unit **820**. The system bus **821** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. Memory and programs described with respect to FIG. **2** can be deployed in corresponding portions of FIG. **13**.

Computer **810** typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by computer **810** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media is different from, and does not include, a modulated data signal or carrier wave. It includes hardware storage media including both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computer **810**. Communication media may embody computer readable instructions, data structures, program modules or other data in a transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal.

The system memory **830** includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) **831** and random access memory (RAM) **832**. A basic input/output system **833** (BIOS), containing the basic routines that help to transfer information between elements within computer **810**, such as during start-up, is typically stored in ROM **831**. RAM **832** typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **820**. By way of example, and not limitation, FIG. **13** illustrates operating system **834**, application programs **835**, other program modules **836**, and program data **837**.

The computer **810** may also include other removable/non-removable volatile/nonvolatile computer storage media. By way of example only, FIG. **13** illustrates a hard disk drive **841** that reads from or writes to non-removable, nonvolatile magnetic media, an optical disk drive **855**, and nonvolatile optical disk **856**. The hard disk drive **841** is typically connected to the system bus **821** through a non-removable memory interface such as interface **840**, and optical disk drive **855** are typically connected to the system bus **821** by a removable memory interface, such as interface **850**.

Alternatively, or in addition, the functionality described herein can be performed, at least in part, by one or more hardware logic components. For example, and without limitation, illustrative types of hardware logic components that can be used include Field-programmable Gate Arrays (FPGAs), Application-specific Integrated Circuits (e.g., ASICs), Application-specific Standard Products (e.g., ASSPs), System-on-a-chip systems (SOCs), Complex Programmable Logic Devices (CPLDs), etc.

The drives and their associated computer storage media discussed above and illustrated in FIG. **13**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **810**. In FIG. **13**, for example, hard disk drive **841** is illustrated as storing operating system **844**, application programs **845**, other program modules **846**, and program data **847**. Note that these components can either be the same as or different from operating system **834**, application programs **835**, other program modules **836**, and program data **837**.

A user may enter commands and information into the computer **810** through input devices such as a keyboard **862**, a microphone **863**, and a pointing device **861**, such as a mouse, trackball or touch pad. Other input devices (not shown) may include a joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit **820** through a user input interface **860** that is coupled to the system bus, but may be connected by other interface and bus structures. A visual display **891** or other type of display device is also connected to the system bus **821** via an interface, such as a video interface **890**. In addition to the monitor, computers may also include other peripheral output devices such as speakers **897** and printer **896**, which may be connected through an output peripheral interface **895**.

The computer **810** is operated in a networked environment using logical connections (such as a local area network—LAN, or wide area network WAN) to one or more remote computers, such as a remote computer **880**.

When used in a LAN networking environment, the computer **810** is connected to the LAN **871** through a network interface or adapter **870**. When used in a WAN networking environment, the computer **810** typically includes a modem **872** or other means for establishing communications over the WAN **873**, such as the Internet. In a networked environment, program modules may be stored in a remote memory storage device. FIG. **13** illustrates, for example, that remote application programs **885** can reside on remote computer **880**.

It should also be noted that the different examples described herein can be combined in different ways. That is, parts of one or more examples can be combined with parts of one or more other examples. All of this is contemplated herein.

Example 1 is an agricultural harvesting machine comprising:

a harvested crop repository having a fill capacity;

a crop processing functionality configured to engage crop in a field, perform a crop processing operation on the crop, and move the processed crop to the harvested crop repository;

a fill level sensor configured to generate a fill level signal indicative of a current fill level of the harvested crop repository;

a path processing system configured to:

obtain a predicted crop yield at a plurality of different field segments along a harvester path on the field;

obtain field data corresponding to one or more of the field segments, the field data being generated based on sensor data from a sensor on the agricultural harvesting machine as the agricultural harvesting machine is performing the crop processing operation;

generate a yield correction factor based on the received field data and the predicted crop yield at the one or more field segments;

based on applying the yield correction factor to the predicted crop yield, generate a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field; and

a control signal generator configured to generate a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

Example 2 is the agricultural harvesting machine of any or all previous examples, wherein the predicted crop yield is based on a priori geo-referenced vegetative index data.

Example 3 is the agricultural harvesting machine of any or all previous examples, wherein the a priori georeferenced vegetative index data is generated based on image data of the field segments.

Example 4 is the agricultural harvesting machine of any or all previous examples, wherein the predicted crop yield is based on historical data from a prior harvesting operation corresponding to the field segments.

Example 5 is the agricultural harvesting machine of any or all previous examples, wherein the sensor comprises a crop yield sensor and the field data comprises crop yield data.

Example 6 is the agricultural harvesting machine of any or all previous examples, wherein the path processing system is configured to:

identify a cumulative predicted crop yield at a plurality of different field segments along the harvester path; and

generate a georeferenced probability distribution, indicative of a probability that the harvested crop repository will reach the fill capacity in the different field segments.

Example 7 is the agricultural harvesting machine of any or all previous examples, and further comprising:

an operator interface mechanism, wherein the control signal generator is configured to generate the control signal to control the operator interface mechanism based on the georeferenced probability metric.

Example 8 is the agricultural harvesting machine of any or all previous examples, wherein the path processing system comprises:

rendezvous point identifier logic configured to identify a rendezvous point for the agricultural harvesting machine and a haulage vehicle, and wherein the control signal generator is configured to generate the control signal based on the rendezvous point.

Example 9 is the agricultural harvesting machine of any or all previous examples, and further comprising:

a communication system, wherein the control signal generator is configured to generate the control signal to control the communication system to communicate an indication of the rendezvous point to the haulage vehicle.

Example 10 is the agricultural harvesting machine of any or all previous examples, and further comprising:

obstacle boundary generation logic configured to generate an obstacle boundary corresponding to one or more obstacles associated with the field, wherein the rendezvous point is identified based on the obstacle boundary.

Example 11 is the agricultural harvesting machine of any or all previous examples, wherein the one or more obstacles are related to at least one of terrain topology or terrain condition.

Example 12 is the agricultural harvesting machine of any or all previous examples, and further comprising:

unload path determination logic configured to determine an unload path, for unloading the harvested crop repository into the haulage vehicle, based on the obstacle boundary.

Example 13 is the agricultural harvesting machine of any or all previous examples, wherein the unload path is based on a predicted unload time for unloading the harvested crop repository into the haulage vehicle.

Example 14 is a method of controlling an agricultural harvesting machine, the method comprising:

obtaining a predicted crop yield at a plurality of different field segments along a harvester path on a field;

processing crop from the field and moving the processed crop to a harvested crop repository having a fill capacity;

obtaining field data corresponding to one or more of the field segments, the field data being generated based on sensor data from a sensor on the agricultural harvesting machine as the agricultural harvesting machine is processing the crop;

generating a yield correction factor based on the received field data and the predicted crop yield at the one or more field segments;

generating a fill level signal indicative of the current fill level of the harvested crop repository;

based on applying the yield correction factor to the predicted crop yield, generating a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field; and

generating a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

Example 15 is the method of any or all previous examples, wherein the predicted crop yield is based on one or more of:

a priori geo-referenced vegetative index data generated based on image data of the field segments, or

historical data from a prior harvesting operation corresponding to the field segments.

Example 16 is the method of any or all previous examples, wherein the sensor comprises a crop yield sensor and the field data comprises crop yield data.

Example 17 is the method of any or all previous examples, and further comprising:

identifying a cumulative predicted crop yield at a plurality of different field segments along the harvester path; and

generating a georeferenced probability distribution, indicative of a probability that the harvested crop repository will reach the fill capacity in the different field segments.

Example 18 is the method of any or all previous examples, and further comprising:

identifying a rendezvous point for the agricultural harvesting machine and a haulage vehicle; and

generating the control signal based on the rendezvous point

Example 19 is the method of any or all previous examples, and further comprising:

generating an obstacle boundary corresponding to one or more obstacles associated with the field; and

identifying the rendezvous point based on the obstacle boundary.

Example 20 is an agricultural harvesting machine comprising:

a harvested crop repository having a fill capacity;

a crop processing functionality configured to engage crop in a field, perform a crop processing operation on the crop, and move the processed crop to the harvested crop repository;

a fill level sensor configured to generate a fill level signal indicative of a current fill level of the harvested crop repository;

a path processing system configured to:
- obtain a predicted crop yield at a plurality of different field segments along a harvester path on the field;
- generate a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field;
- generate an obstacle boundary corresponding to one or more obstacles associated with the field; and
- identify a rendezvous point for the agricultural harvesting machine and a haulage vehicle based on:
  - the georeferenced probability metric, and
  - the obstacle boundary;

a control signal generator configured to generate a control signal to control the agricultural harvesting machine based on the rendezvous point.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed is:

1. An agricultural harvesting machine comprising:
a harvested crop repository having a fill capacity;
a crop processing functionality configured to engage crop in a field, perform a crop processing operation on the crop, and move the processed crop to the harvested crop repository;
a fill level sensor configured to generate a fill level signal indicative of a current fill level of the harvested crop repository;
a path processing system configured to:
obtain a predicted crop yield at a plurality of different field segments along a harvester path on the field;
obtain field data corresponding to one or more of the field segments, the field data being generated based on sensor data from a sensor on the agricultural harvesting machine as the agricultural harvesting machine is performing the crop processing operation;
generate a yield correction factor based on the received field data and the predicted crop yield at the one or more field segments;
based on applying the yield correction factor to the predicted crop yield, generate a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field; and
a control signal generator configured to generate a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

2. The agricultural harvesting machine of claim 1, wherein the predicted crop yield is based on a priori georeferenced vegetative index data.

3. The agricultural harvesting machine of claim 2, wherein the a priori georeferenced vegetative index data is generated based on image data of the field segments.

4. The agricultural harvesting machine of claim 2, wherein the predicted crop yield is based on historical data from a prior harvesting operation corresponding to the field segments.

5. The agricultural harvesting machine of claim 1, wherein the sensor comprises a crop yield sensor and the field data comprises crop yield data.

6. The agricultural harvesting machine of claim 1, wherein the path processing system is configured to:
identify a cumulative predicted crop yield at a plurality of different field segments along the harvester path; and
generate a georeferenced probability distribution, indicative of a probability that the harvested crop repository will reach the fill capacity in the different field segments.

7. The agricultural harvesting machine of claim 1, and further comprising:
an operator interface mechanism, wherein the control signal generator is configured to generate the control signal to control the operator interface mechanism based on the georeferenced probability metric.

8. The agricultural harvesting machine of claim 1, wherein the path processing system comprises:
rendezvous point identifier logic configured to identify a rendezvous point for the agricultural harvesting machine and a haulage vehicle, and wherein the control signal generator is configured to generate the control signal based on the rendezvous point.

9. The agricultural harvesting machine of claim 8, and further comprising:
a communication system, wherein the control signal generator is configured to generate the control signal to control the communication system to communicate an indication of the rendezvous point to the haulage vehicle.

10. The agricultural harvesting machine of claim 8, and further comprising:
obstacle boundary generation logic configured to generate an obstacle boundary corresponding to one or more obstacles associated with the field, wherein the rendezvous point is identified based on the obstacle boundary.

11. The agricultural harvesting machine of claim 10, wherein the one or more obstacles are related to at least one of terrain topology or terrain condition.

12. The agricultural harvesting machine of claim 11, and further comprising:
unload path determination logic configured to determine an unload path, for unloading the harvested crop repository into the haulage vehicle, based on the obstacle boundary.

13. The agricultural harvesting machine of claim 11, wherein the unload path is based on a predicted unload time for unloading the harvested crop repository into the haulage vehicle.

14. A method of controlling an agricultural harvesting machine, the method comprising:
obtaining a predicted crop yield at a plurality of different field segments along a harvester path on a field;
processing crop from the field and moving the processed crop to a harvested crop repository having a fill capacity;
obtaining field data corresponding to one or more of the field segments, the field data being generated based on sensor data from a sensor on the agricultural harvesting machine as the agricultural harvesting machine is processing the crop;
generating a yield correction factor based on the received field data and the predicted crop yield at the one or more field segments;
generating a fill level signal indicative of the current fill level of the harvested crop repository;
based on applying the yield correction factor to the predicted crop yield, generating a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field; and
generating a control signal to control the agricultural harvesting machine based on the georeferenced probability metric.

15. The method of claim 14, wherein the predicted crop yield is based on one or more of:
a priori geo-referenced vegetative index data generated based on image data of the field segments, or
historical data from a prior harvesting operation corresponding to the field segments.

16. The method of claim 15, wherein the sensor comprises a crop yield sensor and the field data comprises crop yield data.

17. The method of claim 15, and further comprising:
identifying a cumulative predicted crop yield at a plurality of different field segments along the harvester path; and

generating a georeferenced probability distribution, indicative of a probability that the harvested crop repository will reach the fill capacity in the different field segments.

18. The method of claim **17**, and further comprising:

identifying a rendezvous point for the agricultural harvesting machine and a haulage vehicle; and

generating the control signal based on the rendezvous point.

19. The method of claim **18**, and further comprising:

generating an obstacle boundary corresponding to one or more obstacles associated with the field; and

identifying the rendezvous point based on the obstacle boundary.

20. An agricultural harvesting machine comprising:

a harvested crop repository having a fill capacity;

a crop processing functionality configured to engage crop in a field, perform a crop processing operation on the crop, and move the processed crop to the harvested crop repository;

a fill level sensor configured to generate a fill level signal indicative of a current fill level of the harvested crop repository;

a path processing system configured to:

obtain a predicted crop yield at a plurality of different field segments along a harvester path on the field;

generate a georeferenced probability metric indicative of a probability that the harvested crop repository will reach the fill capacity at a particular geographic location along the field;

generate an obstacle boundary corresponding to one or more obstacles associated with the field; and

identify a rendezvous point for the agricultural harvesting machine and a haulage vehicle based on:

the georeferenced probability metric, and

the obstacle boundary;

a control signal generator configured to generate a control signal to control the agricultural harvesting machine based on the rendezvous point.

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